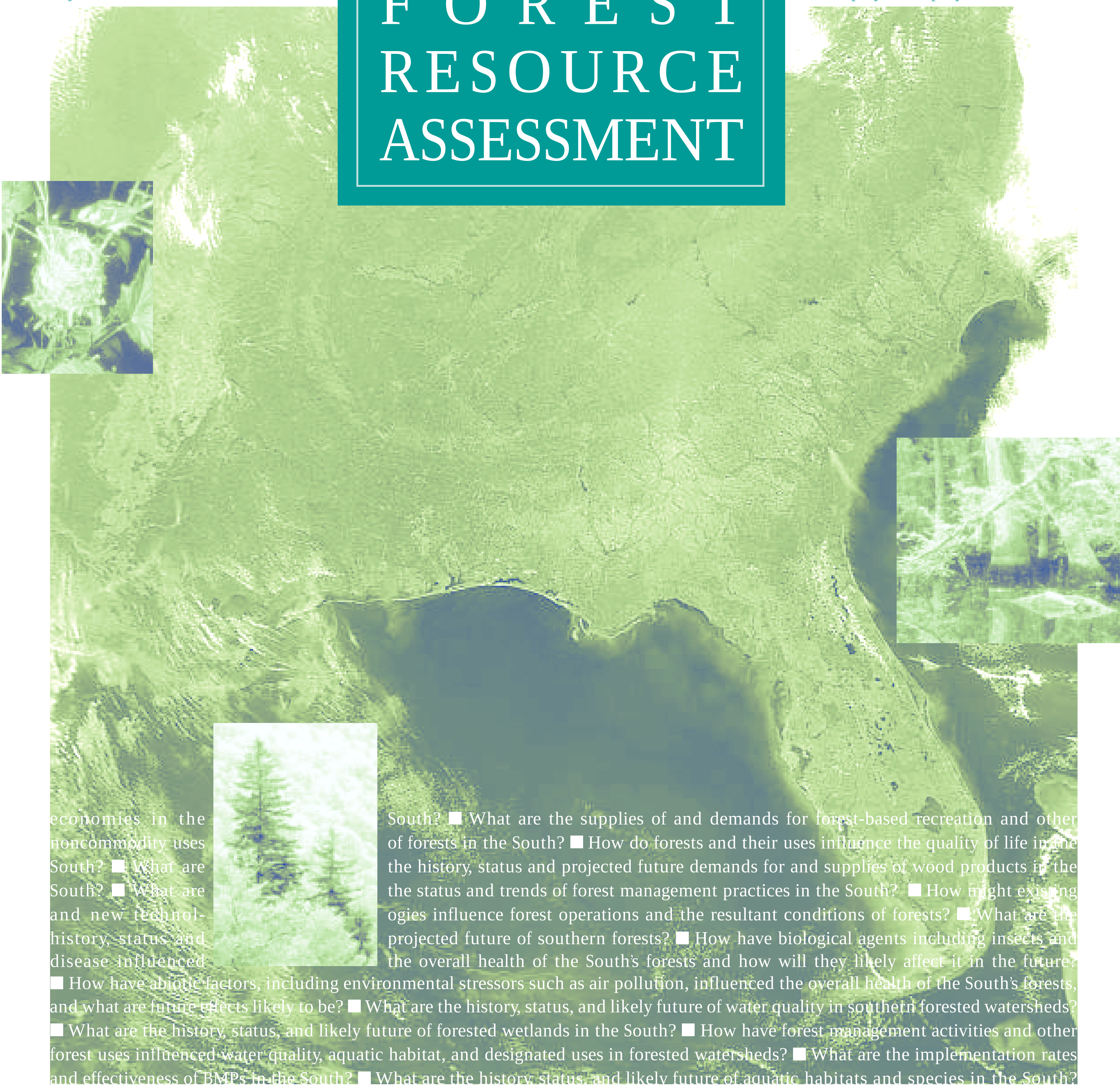
SOUTHERN FOREST RESOURCE ASSESSMENT

■ What are the history, status, and projected future of terrestrial wildlife habitat types and species in the South? ■ What are the history, status and projected future of native plant communities in the South? ■ What are the likely effects of expanding human populations, urbanization and infrastructure development on wildlife and their habitats? ■ What are the historical and projected future impacts of forest management and access on terrestrial ecosystems in the South? ■ What conditions will be needed to maintain animal species associations in the South? ■ How have land uses changed in the South and how might changes in the future affect the area of forests? ■ What are the attitudes and values of southern residents toward forests and their management, and how have they changed over time, and do they differ by demographic groups? ■ How do current policies, regulations, and laws affect forest resources and their management? ■ What motivates private forest landowners to manage their forest land and how are their management objectives formed? ■ What role do forests play in employment and local economies in the South? ■ What are the supplies of and demands for forest-based recreation and other noncommodity uses of forests in the South? ■ How do forests and their uses influence the quality of life in the South? ■ What are the history, status and projected future demands for and supplies of wood products in the South? ■ What are the status and trends of forest management practices in the South? ■ How might existing and new technologies influence forest operations and the resultant conditions of forests? ■ What are the history, status and projected future of southern forests? ■ How have biological agents including insects and disease influenced the overall health of the South's forests and how will they likely affect it in the future? ■ How have abiotic factors, including environmental stressors such as air pollution, influenced the overall health of the South's forests, and what are future effects likely to be? ■ What are the history, status, and likely future of water quality in southern forested watersheds? ■ What are the history, status, and likely future of forested wetlands in the South? ■ How have forest management activities and other forest uses influenced water quality, aquatic habitat, and designated uses in forested watersheds? ■ What are the implementation rates and effectiveness of BMPs in the South? ■ What are the history, status, and likely future of aquatic habitats and species in the South?



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Cover photo: A beautiful spring day in the southeastern United States is seen in this SeaWiFS image. Several smoke plumes are visible including a rather large one that originates in Georgia, midway between the Savannah and Altamaha rivers. A good-sized plume of turbid water can also be seen flushing out of Mobile Bay. Photo courtesy of the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE.

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SOUTHERN FOREST RESOURCE ASSESSMENT

Edited by:

David N. Wear and
John G. Greis

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Dave Wear and John Greis

Coleaders

Southern Forest Resource Assessment

Preface

The Southern Forest Resource Assessment (SFRA) was initiated in 1999 as a result of concerns raised by natural resource managers, the science community, and the public regarding the status and likely future of forests in the South. These included changes to the region's forests brought about by rapid urbanization, increasing timber demand, increasing numbers of satellite chip mills, forest pests, and changing air quality. In response to these issues, leaders of four of the region's Federal natural resource agencies—USDA Forest Service, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and the Tennessee Valley Authority—agreed to work together to provide a careful evaluation of the overall condition and ongoing changes of southern forests. State forestry and fish and wildlife agencies were invited to take part and actively contribute to the effort. The USDA Forest Service, through the Southern Region and Southern Research Station, provided overall leadership. This report and a summary report are the products of a 3-year process that involved much scientific inquiry and public involvement. Because of its role in determining the form of the analysis and products, the process itself deserves description.

The Assessment was organized around a set of questions that defined its intent and scope. Each of the first 23 chapters of this report answers a specific question defined through a public process—
the initial phase of the Assessment. Initial concerns were drafted by a group of about 75 experts from participating government agencies, using a workshop format. They were organized within four broad topic areas—social/economic, terrestrial ecosystems, water and aquatic ecosystems, and forest conditions and health—and then summarized as a preliminary set of Assessment questions. These were presented to the public for discussion and input.

To gather public input, two workshops were conducted at each of five locations around the South. After the audience was presented with an overview of the project's objectives and general design, attendees were invited to take part in any or all of four separate breakout sessions organized around the four broad topic areas. In each of these facilitated sessions, participants were invited to identify concerns and issues that they believed should be addressed by the Assessment. Each session was recorded and the responses compiled. For those who could not attend one of the meetings, initial draft questions were also posted on the Assessment Web site, and comments were welcomed by mail and email. Utilizing the comments received, Assessment leaders crafted another iteration of questions, adding details obtained from public input. A second round of public comment was used to craft the semifinal iteration of questions.

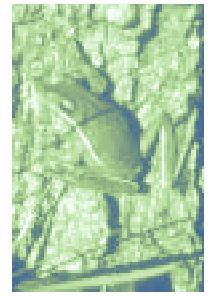
A scientist/analyst was selected by the Assessment Planning Team to conduct the analysis for each question. These individuals, called question managers, comprised the Assessment Team. This team included representatives of the USDA Forest Service, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and academia. In February 2000, the Assessment Team was convened for an initial meeting to finalize their questions, assess the feasibility of addressing the questions, and draft initial study plans. The final Assessment questions are listed after the chapter titles in the "Table of Contents" of this report. Public input was also requested on the draft study plans. Following public review and comment, the plans were finalized, and the analysis was begun.

Each question manager was encouraged to consult with colleagues or to build his/her own research team to complete the work. During the course of the nearly yearlong analysis, two Assessment Team meetings were conducted to discuss progress, share data, and coordinate efforts. These meetings were open to the public but were carefully designed to allow the team to efficiently conduct their business while interacting with the attendees in an organized way. Importantly, preliminary findings were never discussed in open Assessment Team meetings, consistent with a strict team policy that findings not be released piecemeal and without careful peer review.

Responses to each question were drafted by question managers and submitted as separate chapters for the technical report, and Assessment coleaders compiled and synthesized major findings from them for the summary report. All documents were then evaluated using a peer review process patterned after standard approaches utilized by scientific journals. Subject experts were selected from a set of candidates suggested by members of the public, agency representatives on the Assessment Planning Team, and the question managers themselves. A single-blind peer review process was employed—the identities of the reviewers were kept confidential—in order to maximize candor in the reviews. Once received, reviews were compiled and returned to the question managers for consideration as they revised their chapters and finalized them for release in the draft report. On November 26, 2002, the draft chapters (including the summary report) were published via the SFRA Web site and compact disc, and the draft summary report was printed and made available for distribution.

Although draft reports had been peer reviewed by more than 100 experts, the Assessment Planning Team had agreed early in the process to provide the public an opportunity to review them and offer feedback on their accuracy and completeness. Ninety days were provided for this purpose, during which time comments were received via a threaded message board on the SFRA Web site and through the mail. Comments were evaluated and parsed into specific points, organized by chapter, and distributed to question managers for consideration while making final chapter revisions.

The chapters contained in this report represent the Assessment Team's best effort to address the critical issues regarding the status and likely future of southern forests. They provide a synthesis of the available, pertinent literature across a broad suite of scientific disciplines. In addition, they provide insights into where knowledge is lacking and identify topics that warrant additional investigation. We hope that the information contained in this report, along with the glossary and comprehensive datasets available at the Assessment Web site (http://www.srs.fs.fed.us/sustain), will enhance understanding of southern forests, inform public discussion and debate, and improve public forest policies for the benefit of all.



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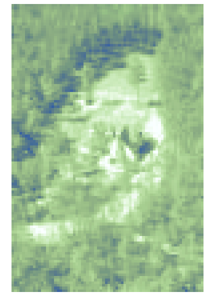

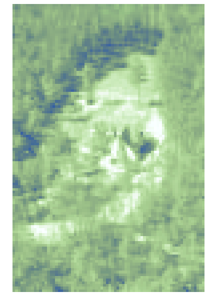

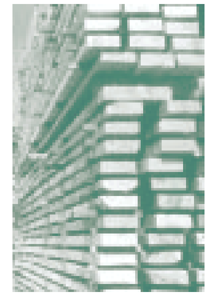

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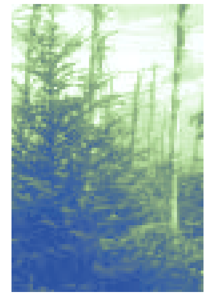

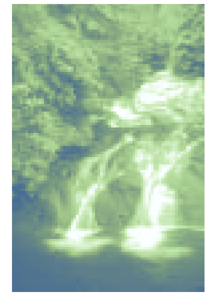

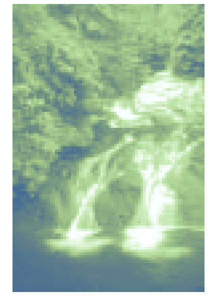
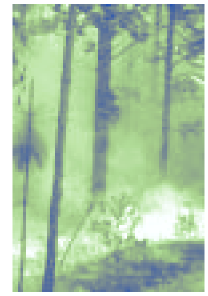

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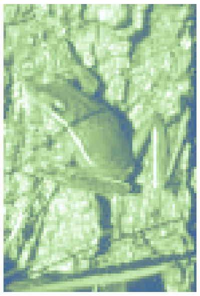
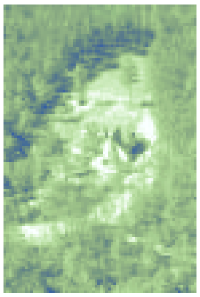
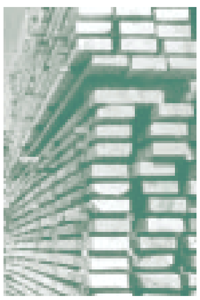
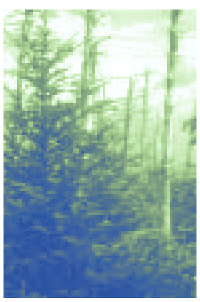
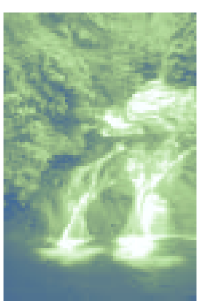
TERRESTRIAL SOCIAL TIMBER HEALTH AQUATIC HISTORY FIRE

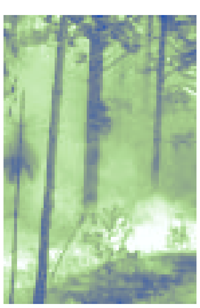












USDA Forest Service
Environmental Protection Agency
U.S. Fish & Wildlife Service
Tennessee Valley Authority

In collaboration with the Southern Group of State Foresters and the Southeastern Association of Fish and Wildlife Agencies

General Technical Report SRS-53

TERRESTRIAL

Photo courtesy U.S Fish & Wildlife Service

What are the history, status, and projected future of terrestrial wildlife habitat types and species in the South?

Chapter 1: Terrestrial Ecosystems

Margaret Katherine Trani (Griep)
Southern Region, USDA Forest Service

Key Findings

■ There are 132 terrestrial vertebrate species that are considered to be of conservation concern in the South by State Natural Heritage agencies. Of the species that warrant conservation focus, 3 percent are classed as critically imperiled, 3 percent as imperiled, and 6 percent as vulnerable. Eighty-six percent of terrestrial vertebrate species are designated as relatively secure. The remaining 2 percent are either known or presumed to be extinct, or have questionable status.

■ Species of conservation concern are dominated by amphibians and reptiles. Fifty-four amphibians, 40 reptiles, 20 birds, and 18 mammals are classed as imperiled.

■ Increasing population trends are reported for wild turkey, white-tailed deer, and black bear. Populations of northern bobwhite quail, gray fox, and red squirrels have declined for several years. There have also been declines in mourning dove and American woodcock populations. Cottontail rabbit and ruffed grouse populations have demonstrated cyclical patterns. Among the migratory game birds, record harvests of ducks and geese have occurred in recent years.

■ Groups of nongame birds with more than 50 percent of their species showing significant declining trends include grassland-nesting birds (70 percent), ground-nesting birds (57 percent), and shrubland-nesting birds (53 percent).

■ Since presettlement, there have been significant losses of community biodiversity in the South (Noss and others 1995). Fourteen communities are critically endangered (greater than 98-percent decline), 25 are endangered (85- to 98-percent decline), and 11 are threatened (70- to 84-percent decline). Common factors contributing to the loss of these communities include urban development, fire suppression, exotic species invasion, and recreational activity.

■ The term “fragmentation” references the insularization of habitat on a landscape. The change in arrangement of remaining habitats can be accompanied by a loss of habitat area. Habitat fragmentation can result in the decline of interior-dwelling birds; the decline of some large, wide-ranging species; and the loss of other specialized species. Habitat fragmentation affects the patch, connectivity, and edge characteristics of a landscape.

■ Connectivity within a landscape may facilitate movement and fecundity for some species, while the size and shape of landscape patches influences the integrity of both biotic and abiotic processes. Edge characteristics also have important implications for the persistence of an array of terrestrial species with very different habitat requirements.

■ The availability of hard and soft mast can influence some terrestrial vertebrate species. Mast is an essential component in the diet of many birds and mammals. Disease, insect infestation, advanced age, climatic processes, and disturbance influence mast yields.

■ The ranges of many species cross both public and private land ownerships. The numbers of imperiled and endangered species inhabiting private land indicate its critical importance for conservation.

■ The significance of land ownership in the South for the provision of species habitat cannot be overstated. Each major landowner has an important role to play in the conservation of species and their habitats.

Introduction

The South has an impressive diversity of terrestrial communities and species associations. These communities range from mountain spruce-fir forests to tropical hardwoods, and from coastal dunes to prairies. Centuries of settlement and land use change have brought a number of threats and pressures. The majority of the landscape has been modified considerably, resulting in the disappearance, degradation, and endangerment of native communities.

This chapter assesses the historical and present status of terrestrial species across the South. It is organized into six major sections:

1. An overview of southern historical conditions affecting terrestrial vertebrate species.

2. A review of populations, harvests, and the conservation status of species occurring in the South.

3. A review of selected sensitive communities in the region and the common threats to these communities.

4. An overview of vertebrate species that consume hard and soft mast. This section also lists several mast-producing species that occur in the South.

5. An evaluation of the significance of public and other land for maintaining species and their habitats.

6. A review of the literature on fragmentation and its influence on landscapes and the species supported by those landscapes.

Several species are included that, at one stage or another of their lives, return to land to reproduce or spend a part of their lives there. The focus is on vertebrates because information on the regional biogeography of many terrestrial invertebrate groups is lacking (Echternacht and Harris 1993). Scientific names are provided in the chapter tables; therefore, common names will be used in the text. (Note: Additional information on the status and habitat relationships of vertebrate resources across the South is provided in chapters 5 and 23, which include discussions of threatened and endangered species.)

Methods and Data Sources

Data on the conservation status of terrestrial vertebrate species were compiled from State Natural Heritage agencies using NatureServe (2000). The Natural Heritage database is an inventory of known occurrences for species of conservation concern, including federally listed species. Stein and others (2000) list multiple criteria used by Natural Heritage for assessing conservation status: occurrence (number of distinct populations or subpopulations); condition (viability of extant populations); population size; area of occupied habitat; short- and long-term population trends; known or suspected threats; susceptibility to intrinsic biological factors; and the number of protected occurrences. This methodology provides the basis for conservation status designations that indicate the degree of imperilment.

Species known to be extinct (GX), or possibly extinct (GH), are recorded independently. For example, the passenger pigeon is assigned the GX ranking because there is no question about its extinction. For a considerable number of species that have not been observed in many years, however, there remains some hope of rediscovery. That, for example, is the case for Bachman's warbler. These species were assigned the status of GH.

Information on game and furbearer abundance was obtained from the Renewable Resources Planning Act (RPA) Wildlife Report (Flather and others 1999). The RPA is a periodic assessment of natural resources on the Nation's forests and rangelands. The RPA data on game populations originated from State agencies using questionnaires developed by the USDA Forest Service and the Natural Resources Conservation Service. Data from the RPA assessments are taken from various State and Federal agencies. Population projections of harvested animals are based on surveys of experts from State wildlife agencies.

Information on rare and threatened communities was based on the comprehensive reviews conducted by Grossman and others (1994), Noss and others (1995), White and others (1998), and Walker (2001).

Information on the acreage and distribution of Federal land was obtained from the National Parks index (U.S. Department of the Interior 2000a), the Lands Report from the Fish and Wildlife Service (U.S. Department of Interior 2000b), and the Lands Area Report of the USDA Forest Service (U. S. Department of Agriculture, Forest Service 2000c). Agency reports also were compiled for national parks (U.S. Department of the Interior, Park Service 2000) and national refuges (U.S. Department of the Interior, Fish and Wildlife Service 2000), providing property descriptions and species lists.

Statewide timberland ownership data were obtained from the Forest Inventory and Analysis Research Work Unit (FIA) of the Southern Research Station (U.S. Department of Agriculture, Forest Service 2000a). For each State, the acres in both public and private ownership categories were analyzed.

A literature search was conducted for information on fragmentation, rare communities, historical conditions, and species habitat relationships. In addition, research stations and universities throughout the South were contacted to obtain additional information. The results from this effort were combined with additional information obtained from several plant and animal field guides. A list of mast-producing species was compiled using vegetation guides; terrestrial vertebrate species that include mast as a component of their diet were extracted from wildlife field guides.

Results

Historical Conditions

The presettlement landscape of the South was quite diverse: forests of different ages were interspersed with expansive savannas, dense cane thickets, barrens, and swamps. Disturbance was a major influence on the composition of southern forests, creating forest openings and resetting succession (Lorimer 2001). Forests were dynamic; natural succession progressed with shade-tolerant plants replacing pioneer species. Periodic flooding and associated sedimentation influenced the distribution and composition of local areas.

Frequent thunderstorms provided a source of natural fires, resulting in a landscape of mixed species composition. Lightning fires burned unabated (Williams 1989). Fire frequency and intensity were dominant forces (refer to chapter 25). Fire was important for the persistence of many communities including pine forests, oak-hickory forests, savannas, barrens, and prairies (Trani and others 2001).

Native Americans, through use of fire and crop cultivation (Buckner 1989, Delcourt and Delcourt 1987), further modified the composition and open character of the forest. Fires were frequently set to create openings for crops and to drive game for harvest. The effects of native inhabitation on southern forests were extensive (refer to chapter 24).

Wildlife of the presettlement South was quite impressive. Dickson (2001) describes large herds of bison and elk roaming throughout the prairies and savannas of the region. White-tailed deer and wild turkey also were numerous. Large carnivores (black bear, cougar, red wolf, and bobcat) were abundant, and a diversity of successional seres supported a variety of prey populations. Other mammals included mink, muskrat, river otter, beaver, gray fox, red fox, spotted skunk, long-tailed weasel, bats, and numerous small mammals.

Birds present in today's forests also were likely present during presettlement (Dickson 2001). Raptors such as the Mississippi kite, bald eagle, osprey, red-shouldered hawk, and barred owl were likely occupants of historic bottomland forests. The Swainson's and Bachman's warblers inhabited cane thickets, while the yellow-breasted chat and indigo bunting populated young forests. Cavity-nesting birds such as red-headed woodpeckers, American kestrels, and great crested flycatchers were abundant in the old-growth forests of eastern Texas (Truett and Lay 1984). The ivory-billed woodpecker thrived in oak-gum forests, foraging on snags for insects.

Early records of reptiles and amphibians are limited, but these records make frequent reference to rattlesnakes and alligators (Dickson 2001). Historic forest habitats appear to have supported viable, diverse populations of herpetofauna (Gibbons and Buhlman 2001).

Extensive inundated bottomland forests supported habitat for millions of wood ducks and mallards (Heitmeyer 2001). Wood ducks commonly nested in the cavities of abundant old-growth forests. Hooded mergansers, green-winged teal, gadwall, and American widgeon also frequented flooded bottoms.

The southern landscape changed dramatically with the advent of European settlers. Settlement resulted in the extensive clearing of forest and conversion of the land to pasture or cropland (DeGraaf and Miller 1996). These lands were often managed with fire, which was also used to maintain savannas and other open areas in the East (Williams 1989). In particular, fire was used to create favorable grazing conditions for domestic animals (Healy 1985).

By 1819, all land was claimed east of the Mississippi River (Dickson 2001). Natural resources were treated as if they were inexhaustible. Forests were cut with little thought for forest regeneration, and soils were seriously depleted through erosion and excessive cropping. Wildlife species and their habitats were likewise exploited without concern for their persistence. The decline in abundance of wildlife that occurred during the last half of the 19th century remains unparalleled in the history of the South.

Deer populations nationwide plummeted to fewer than a million animals by 1900 (Dickson 2001). Bison and elk disappeared from the region. The wild turkey disappeared from several States within its range. The wood duck was drastically reduced by indiscriminate harvest. Populations of large carnivores, regarded as threats to livestock and people, were decimated, and viable populations of black bear and cougar were relegated to relatively remote areas.

The loss of bottomland forest in the Mississippi Alluvial Valley affected waterfowl and other species that were displaced into adjacent areas. Harvests of the passenger pigeon and the Carolina parakeet for market led to their demise in the early 1900s (table 1.1). Market hunting, the domestication of land, and the harvest of mature forests without regeneration led to the extirpation of some species in various Southern States (table 1.2). (Note: It is possible that some species were extirpated because their range is on the periphery of the region. Their loss may be related to random effects associated with low populations at the edges of their ranges.)

During the 1930s and 1940s, the States recognized the dire status of wildlife populations and initiated efforts to address the problem. The Duck Stamp Act (1934), the Pittman-Robertson Act (1937), and the Dingle-Johnson Act (1950) apportioned funds to States for wildlife restoration projects, habitat acquisition, and research.

These efforts came too late for some species (table 1.1). The ivory-billed woodpecker foraged in mature bottomland hardwoods along the Atlantic and Gulf coasts. Its diet consisted of wood-boring insect larvae occurring in dead and dying trees. Overhunting and intensive harvesting of virgin hardwood forests between the 1880s and 1920s led to the decline of this species (U.S. Department of the Interior 1973).

Table 1.1—Terrestrial vertebrate species classified as presumed or possibly extinct in the South

Scientific name	Common name	Former areas of occurrence
Presumed extinct		
Conuropsis carolinensis	Carolina parakeet	AL, AR, FL, GA, LA, MS, NC, OK, SC, TN, TX, VA
Ectopistes migratorius	Passenger pigeon	AL, AR, FL, GA, LA, MS, NC, OK, SC, TN, TX, VA
Monachus tropicalis	West Indian monk seal	FL
Possibly extinct		
Campephilus principalis	Ivory-billed woodpecker	AL, AR, FL, GA, LA, MS, NC, OK, SC, TN, TX
Eurycea troglodytes	Valdina farms sinkhole salamander	TX
Plethodon ainsworthi	A plethodontid salamander	MS
Vermivora bachmanii	Bachman's warbler	AL, MS, OK, SC, TN, VA

Source: NatureServe 2000.

Table 1.2—Vertebrate species extirpated from selected States within the South

Scientific name	Common name	Former areas of occurrence
Mammals		
Rodents		
Erethizon dorsatum	Common porcupine	NC, VA
Microtus ochrogaster	Prairie vole	LA
Carnivores		
Canis lupus	Gray wolf	AR, GA, KY, NC, OK, TN, TX, VA
Canus rufus	Red wolf	AL, AR, FL, GA, KY, LA, OK, TX, VA
Leopardus pardalis	Ocelot	AR, LA
Leopardus wiedii	Margay	TX
Martes pennanti	Fisher	NC, TN
Mustela nigripes	Black-footed ferret	OK
Panthera onca	Jaguar; otorongo	LA
Puma concolor	Mountain lion	AL
Ursus arctos	Grizzly or brown bear	OK, TX
Other mammals		
Bos bison	American bison	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, VA
Cervus elaphus	Wapiti or elk	AL, AR, GA, KY, LA, NC, OK, SC, TN, VA
Lepus americanus	Snowshoe hare	NC
Birds		
Wading birds		
Grus americana	Whooping crane	AR, FL, KY
Waterfowl		
Cygnus buccinator	Trumpeter swan	KY, LA
Shorebirds		
Bartramia longicauda	Upland sandpiper	TN
Numenus borealis	Eskimo curlew	OK, SC
Perching birds		
Corvus corax	Common raven	AL
Other birds		
Anhinga anhinga	Anhinga	KY
Centrocercus urophasianus	Sage grouse	KS, OK
Geotrygon chrysia	Key West quail-dove	FL
Tympanuchus cupido	Greater prairie chicken	AR, KY, LA, TN
Tympanuchus phasianellus	Sharp-tailed grouse	OK, TX
Zenaida aurita	Zenaida dove	FL
Reptiles		
Snakes		
Masticophis flagellum	Coachwhip	KY

Source: NatureServe 2000.

Bachman's warbler, last observed in the 1960s, once inhabited Arkansas, Kentucky, Alabama, South Carolina, Louisiana, and Missouri. The extensive clearing of bamboo and canebrake habitat for agriculture along the Mississippi River and West Gulf Coastal Plains bottoms degraded the wintering and breeding habitat for this species (Ehrlich and others 1992). Excessive collecting for the millinery trade may also have contributed to the decline.

The Valdina Farms salamander was endemic to Texas. The amphibian occurred in isolated, intermittent pools. It is now extinct due to flooding of its only known habitat. Populations of the West Indian monk seal, which originally inhabited the Florida coast, were decimated during the 19th century. The major factor in its extermination was over-hunting, principally for blubber (to make oil) and for meat. The seal's inherent tameness increased its vulnerability to slaughter.

The last four decades of the 20th century brought legislation that furthered species conservation efforts, including the Wilderness Act (1964), the Endangered Species Act (1966, 1969, and 1973), the National Environmental Policy Act (1970), the Marine Mammal Protection Act (1971), and the National Forest Management Act (1976). Through these and several other conservation efforts, conditions for many species have improved across the South (Dickson 2001). However, the loss and modification of unique forest communities continues to affect populations of other species. The remainder of this chapter examines these influences, presenting the trends for a diversity of southern species.

Status and Trends of Terrestrial Vertebrate Species

Conservation status ranks for southern species—The databases of the State Natural Heritage agencies were used to derive a regional species list of global (G) conservation ranks. The G ranks reflect a species' rarity throughout its range. For example, a species holding the G conservation ranking of G1 in Virginia also carries the same rank elsewhere in the Nation.

These ranks are: GX (presumed extinct: intensive search has not located additional populations); GH (possibly extinct: historically known and may be rediscovered); G1 [critically imperiled globally because of extreme rarity (observations include 5 or fewer locations or fewer than 1,000 animals)] or because some factor of its biology makes it vulnerable to extinction]; G2 [imperiled globally because of rarity (observations reflect 6 to 20 locations or 1,000 to 3,000 animals)] or because of other factors making it vulnerable to extinction]; G3 [vulnerable globally because of rarity throughout its range (observations include 21 to 100 locations or 3,000 to 10,000 animals) or because it is found locally in a restricted area]; G4 (apparently secure globally, although the species may be rare in parts of its range, especially at the periphery; usually more than 100 occurrences and 10,000 individuals); and G5 (secure globally: observations are common and widespread).

Figure 1.1 shows the proportion of vertebrate taxa in each of the conservation ranking categories. One hundred thirty-two species are considered to be of conservation concern. Among terrestrial vertebrates, 28 species are classified as critically imperiled, 37 species as imperiled, and 67 species as vulnerable. Eighty-six percent of southern terrestrial vertebrate species are designated as relatively secure by Natural Heritage.

Figure 1.2 shows species ranked as presumed or possibly extinct, critically imperiled, imperiled, or vulnerable among the four major vertebrate taxa. Collectively, these species represent animals with elevated risks of extinction or of conservation concern.

The proportion of species at risk varies greatly among taxonomic groups. Forty-one percent of imperiled species are amphibians, followed by reptiles (30 percent), birds (15 percent), and mammals (14 percent). With the exception of mammals, the number of species at risk within each taxonomic group is not proportionate with their respective richness in the region. For example, amphibian species comprise only 14 percent of the terrestrial vertebrates occurring in the South, yet they comprise 41 percent of the imperiled species list. Conversely, bird species comprise 48 percent of southern terrestrial vertebrates, but only 15 percent of the imperiled species. Refer to chapter 5 for additional data on regional species richness.

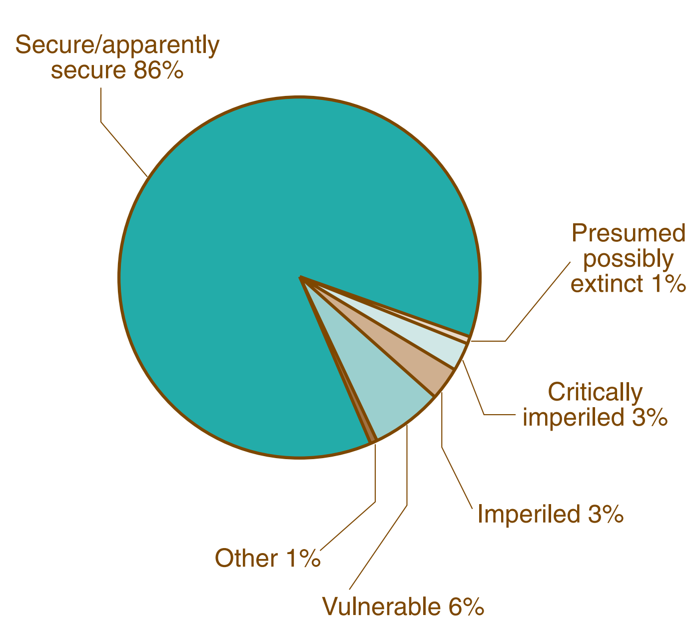


Figure 1.1—Proportion of southern terrestrial vertebrate species at risk. The Other category includes species that have not been ranked or have questionable status (NatureServe 2000).

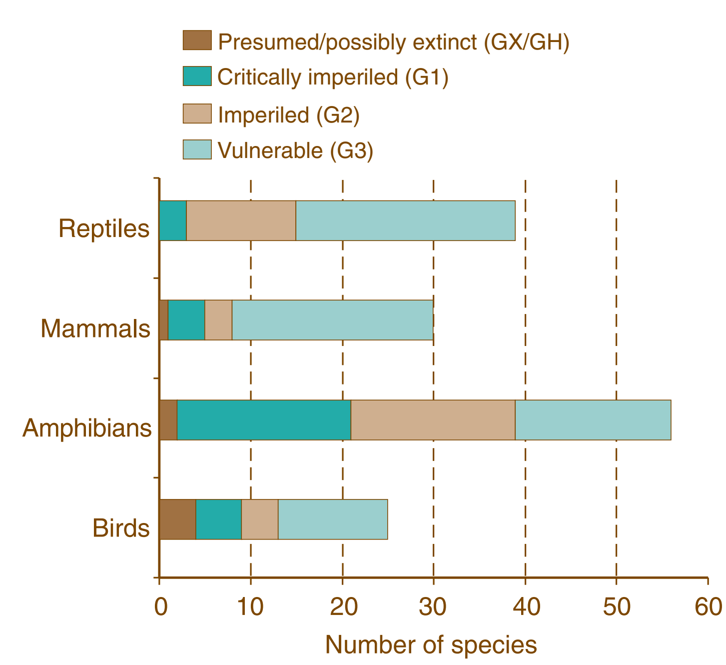


Figure 1.2—Number of terrestrial vertebrate species at risk delineated by major taxa in the South (NatureServe 2000).

Table 1.3—Amphibian species within the South with global rankings of G1, G2, and G3

Scientific name	Common name	Areas of occurrence
Frogs and toads		
G1		
Bufo houstonensis	Houston toad	TX
G2		
Rana okaloosae	Florida bog frog	FL
G3		
Rana capito	Gopher frog	AL, FL, GA, LA, MS, NC, SC, TN
Salamanders		
G1		
Desmognathus sp.1	Waterrock knob salamander	NC
Eurycea latitans	Cascade caverns salamander	TX
Eurycea nana	San Marcos salamander	TX
Eurycea neotenes	Texas salamander	TX
Eurycea rathbuni	Texas blind salamander	TX
Eurycea robusta	Blanco blind salamander	TX
Eurycea sosorum	Barton Springs salamander	TX
Eurycea sp. 1	Jollyville Plateau salamander	TX
Eurycea sp. 2	Salado Springs salamander	TX
Eurycea sp. 4	Buttercup Creek caves salamander	TX
Eurycea sp. 5	Georgetown salamander	TX
Eurycea sp. 6	Pedernales River spring salamander	TX
Eurycea sp. 7	Edwards Plateau spring salamander	TX
Eurycea sp. 8	Comal Springs salamander	TX
Eurycea tridentifera	Comal Blind salamander	TX
Plethodon petraeus	Pigeon Mountain salamander	GA
Plethodon shenandoah	Shenandoah salamander	VA
Notophthalmus meridionalis	Black-spotted newt	TX
G2		
Ambystoma cingulatum	Flatwoods salamander	AL, FL, GA, SC
Desmognathus carolinensis	Carolina mountain dusky salamander	NC, TN
Desmognathus ocoee	Ocoee salamander	AL, GA, NC, SC, TN
Desmognathus orestes	Blue Ridge dusky salamander	NC, VA
Eurycea pterophila	Blanco River Springs salamander	TX
Gyrinophilus palleucus	Tennessee cave salamander	AL, GA, TN
Haideotriton wallacei	Georgia blind salamander	FL, GA
Phaeognathus hubrichti	Red hills salamander	AL
Plethodon aureolus	Tellico salamander	NC, TN
Plethodon caddoensis	Caddo Mountain salamander	AR
Plethodon fourchensis	Fourche Mountain salamander	AR
Plethodon hubrichti	Peaks of Otter salamander	VA
Plethodon ouachitae	Rich Mountain salamander	AR,OK
Plethodon virginia	Shenandoah mountain salamander	VA
Necturus alabamensis	Black warrior waterdog	AL
Notophthalmus perstriatus	Striped newt	FL, GA
Siren sp. 1	Lesser siren (Rio Grande population)	TX
G3		
Amphiuma pholeter	One-toed amphiuma	AL, FL, GA, MS
Aneides aeneus	Green salamander	AL, GA, KY, MS, NC, SC, TN, VA
Desmognathus aeneus	Seepage salamander	AL, GA, NC, SC, TN
Desmognathus apalachicolae	Apalachicola dusky salamander	AL, FL, GA
Desmognathus brimleyorum	Ouachita dusky salamander	AR, OK
Desmognathus imitator	Imitator salamander	NC, TN

(continued)

Table 1.3—Amphibian species within the South with global rankings of G1, G2, and G3 (continued)

Scientific name	Common name	Areas of occurrence
Salamanders (cont.)		
G3 (cont.)		
Desmognathus santeetlah	Santeetlah dusky salamander	NC, TN
Desmognathus wrighti	Pigmy salamander	NC, TN, VA
Eurycea junaluska	Junaluska salamander	NC, TN
Eurycea sp. 9	Sandhills salamander	NC
Eurycea tynerensis	Oklahoma salamander	AR, OK
Plethodon punctatus	White-spotted salamander	VA
Plethodon teyahalee	Southern Appalachian salamander	GA, NC, TN
Plethodon websteri	Webster's salamander	AL, GA, LA, MS, SC
Plethodon welleri	Weller's salamander	NC, TN, VA
Necturus lewisi	Neuse River waterdog	NC

G1 = critically imperiled; G2 = imperiled; G3 = vulnerable.
Source: NatureServe 2000.

The conservation status of individual species are presented in tables 1.3, 1.4, 1.5, and 1.6. Several of these species are discussed in further detail in chapters 5 and 23, including the factors influencing imperilment and species habitat relationships. Species that are federally listed as threatened or endangered are discussed in chapter 5.

Fifty-four amphibian species are of conservation concern (table 1.3). Salamanders dominate with 51 listings; frogs and toads have 3 listings. Examples include the Houston toad, gopher frog, flatwoods salamander, Ocoee salamander, green salamander, and several species in the Plethodon, Desmognathus, and Eurycea genera.

Forty reptile species are imperiled or vulnerable (table 1.4). Reptile subgroups with global rankings of concern include turtles (19), lizards (10), snakes (9), and others (2). Oceanic and map turtles dominate this list. Other reptiles of conservation concern include the alligator snapping turtle, bog turtle, gopher tortoise, glass lizard, southern hognose snake, and crocodile.

Twenty avian species are of concern (table 1.5). Subtaxa include 2 wading birds, 3 shorebirds, 6 perching birds, and 9 others. Several of these species include the whooping crane, piping plover, Bachman's sparrow, Florida scrub jay, red-cockaded woodpecker, and lesser prairie chicken.

Eighteen mammal species are imperiled or vulnerable (table 1.6). Mammalian subtaxa with global rankings of concern include 5 bats, 8 rodents, 3 carnivores, and 2 others. Bats are represented by the Indiana bat, Rafinesque's big-eared bat, southeastern myotis, and several other species. Additional mammals include the Allegheny wood rat, red wolf, and swift fox.

Population and harvest trends for southern species—The regional population and harvest trends presented in this section, unless otherwise stated, originated from the RPA (Flather and others 1999). The RPA represented the best source of quantitative data on regional trends for multiple species at the time of this Assessment. Information was collected from cooperating State wildlife agencies. Population estimates were summed across those States that provided data. (The list of States that provided population estimates is available at the Rocky Mountain Research Station, Fort Collins, CO.) The absence of data from certain States resulted from variation in the distribution of species or the lack of data for certain years. The RPA included only States that provided estimates for 1975 to 1990 (in 5-year intervals) and 1993 in the trend analysis.

Projections were based on a weighted average percentage change from 1993 to the year 2000 and 2045 for States that provided projection estimates. The average percentage change was then applied to the 1993 population estimate in order to extrapolate a total projected population for States that provided population estimates (Flather and others 1999).

Population and harvest trends for southern species: big game species—Big game species are primarily large mammals taken for sport or subsistence. Because of State agency convention, the wild turkey also is included. The species comprising big game were the first to stimulate widespread public interest in wildlife conservation. For this reason, historical information about game species is extensive for several States.

Wild turkey populations have consistently increased since 1975 (fig. 1.3). Five States project that turkey populations will decline over the next four decades (Flather and others 1999).

For States reporting on white-tailed deer, populations have increased approximately fourfold since 1975 (fig. 1.4). There is concern among State personnel that deer may become a management problem during the next decade. Seven States expect deer numbers to decline slightly over the next 50 years (Flather and others 1999). (Additional information on deer is provided in chapters 3, 4, and 5.)

The trend in black bear numbers is positive for the four States reporting (fig. 1.5). Biologists from these States expect bear populations to decline somewhat over the next few decades (Flather and others 1999). (Note: The Florida and Louisiana subspecies of

Table 1.4—Reptile species within the South with global rankings of G1, G2, and G3

Scientific name	Common name	Areas of occurrence
Turtles		
G1		
Lepidochelys kempii	Kemp's or Atlantic ridley	AL, FL, GS, LA, MS, NC, TX, VA
Pseudemys alabamensis	Alabama redbelly turtle	AL, FL, MS
G2		
Sternotherus depressus	Flattened musk turtle	AL
Graptemys barbouri	Barbour's map turtle	AL, FL, GA
Graptemys ernsti	Escambia map turtle	AL, FL
Graptemys flavimaculata	Yellow-blotched map turtle	MS
Graptemys oculifera	Ringed map turtle	LA, MS
G3		
Macroclemys temminckii	Alligator snapping turtle	AL, AR, FL, GA, KY, LA, MO, MS, OK, TN, TX
Caretta caretta	Loggerhead	AL, FL, GA, LA, MS, NC, SC, TX, VA
Chelonia mydas	Green turtle	AL, FL, GA, LA, MS, SC, TX, VA
Eretmochelys imbricata	Hawksbill	AL, FL, GA, LA, MS, NC, SC, TX
Dermochelys coriacea	Leatherback tinglar	AL, FL, GA, LA, MS, NC, TX, VA
Kinosternon hirtipes	Mexican mud turtle	TX
Clemmys muhlenbergii	Bog turtle	GA, NC, SC, TN, VA
Gopherus polyphemus	Gopher tortoise	AL, FL, GA, LA, MS, SC
Graptemys caglei	Cagle's map turtle	TX
Graptemys gibbonsi	Pascagoula map turtle	LA, MS
Graptemys nigrinoda	Black-knobbed map turtle	AL, MS
Trachemys gaigeae	Big bend slider	TX
Lizards		
G2		
Sceloporus arenicolus	Sand dune lizard	TX
Neoseps reynoldsi	Sand skink	FL
G3		
Crotaphytus reticulatus	Reticulate collared lizard	TX
Holbrookia lacerata	Spot-tailed earless lizard	TX
Holbrookia propinqua	Keeled earless lizard	TX
Sceloporus woodi	Florida scrub lizard	FL
Coleonyx reticulatus	Reticulated gecko	TX
Cnemidophorus dixoni	Gray-checkered whiptail	TX
Ophisaurus compressus	Island glass lizard	FL, GA, SC
Ophisaurus mimicus	Mimic glass lizard	AL, FL, GA, MS, NC, SC
Snakes		
G1		
Tantilla oolitica	Rim Rock crowned snake	FL
G2		
Clonophis kirtlandii	Kirtland's snake	KY
Heterodon simus	Southern hognose snake	AL, FL, GA, MS, NC, SC
Nerodia harteri	Brazos water snake	TX
Nerodia paucimaculata	Concho water snake	TX
G3		
Pituophis ruthveni	Louisiana pine snake	LA, TX
Stilosoma exenuatum	Short-tailed snake	FL
Tantilla atriceps	Mexican blackhead snake	TX
Sistrurus catenatus	Massasauga	OK, TX
Other reptiles		
G2		
Crocodylus acutus	American crocodile	FL
G3		
Caiman crocodilus	Spectacled caiman	FL, GA

G1 = critically imperiled; G2 = imperiled; G3 = vulnerable.
Source: NatureServe 2000.

Table 1.5—Bird species within the South with global rankings of G1, G2, and G3

Scientific name	Common name	Areas of occurrence
Wading birds		
G1		
Grus Americana	Whooping crane	AL, GA, LA, OK, TX
G3		
Phoenicopterus ruber	Greater flamingo	FL
Shorebirds		
G1		
Numenus borealis	Eskimo curlew	AR, LA, NC, TX
G2		
Charadrius montanus	Mountain plover	OK, TX
G3		
Charadrius melodus	Piping plover	AL, AR, FL, GA, KY, LA, MS, NC, OK, TN, TX, VA
Perching birds		
G2		
Dendroica chrysoparia	Golden-cheeked warbler	TX
Vireo atricapillus	Black-capped vireo	MS, OK, TX
G3		
Aimophila aestivalis	Bachman's sparrow	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Aphelocoma coerulescens	Florida scrub jay	FL
Pipilo alberti	Albert's towhee	TX
Vermivora crissalis	Colima warbler	TX
Other birds		
G1		
Pterodroma feae	Fea's petrel	NC
Pterodroma hasitata	Black-capped petrel	FL, GA, NC, VA
G2		
Amazona viridigenalis	Red-crowned parrot	FL, TX[a]
G3		
Columba leucocephala	White-crowned pigeon	FL, TX
Pelecanus erythrorhynchos	American white pelican	AL, AR, FL, GA, KY, LA, MS, NC, OK, TN, TX
Picoides borealis	Red-cockaded woodpecker	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Strix occidentalis	Spotted owl	TX[a]
Thalassarche chlororhynchos	Yellow-nosed albatross	FL, NC
Tympanuchus pallidicinctus	Lesser prairie chicken	OK, TX

G1 = critically imperiled; G2 = imperiled; G3 = vulnerable.
[a] West Texas.
Source: NatureServe 2000.

black bear, of conservation concern in the region, are discussed separately in chapter 5.)

Population and harvest trends for southern species: small game species—Species classified as small game typically include resident game birds and mammals that are associated with upland (forest, range, or agricultural) habitats. There is some variation among State wildlife agencies as to which species are managed as small game. In this chapter, quail, grouse, rabbits, and squirrels are considered small game. Few State wildlife agencies monitor small game populations; therefore, the trends reviewed here should be interpreted carefully.

The populations of gray, red, and fox squirrels have been declining in the South since 1985 (fig. 1.6). Cottontail rabbit populations declined slightly between 1975 and 1980 (fig. 1.7), but recovered by 1990. One State projects that cottontail rabbit populations may decline by 2045 (Flather and others 1999).

Northern bobwhite quail populations have declined from 1975 to the present (fig. 1.8). Among the States reporting trends in bobwhite abundance, populations have declined by nearly

Table 1.6—Mammal species within the South with global rankings of G1, G2, and G3

Scientific name	Common name	Areas of occurrence
Bats		
G2		
Myotis sodalis	Indiana or social myotis	AL, AR, KY, NC, OK, SC, TN, VA
G3		
Corynorhinus rafinesquii	Rafinesque's big-eared bat	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Myotis austroriparius	Southeastern myotis	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Myotis grisescens	Gray myotis	AL, AR, FL, GA, KY, OK, SC, TN, VA
Myotis leibii	Eastern small-footed myotis	AL, AR, GA, KY, NC, OK, SC, TN, VA
Rodents		
G1		
Dipodomys elator	Texas kangaroo rat	OK, TX
G2		
Geomys texensis	Llano pocket gopher	TX
G3		
Tamias canipes	Gray-footed chipmunk	TX
Geomys arenarius	Desert pocket gopher	TX
Geomys knoxjonesi	Jones' pocket gopher	TX
Neofiber alleni	Round-tailed muskrat	FL, GA
Neotoma magister	Allegheny woodrat	AL, KY, NC, TN, VA
Podomys floridanus	Florida mouse	FL
Carnivores		
G1		
Canus rufus	Red wolf	NC, SC, TN
G3		
Vulpes velox	Swift fox	OK, TX
Panthera onca	Jaguar; otorongo	TX
Other mammals		
G2		
Trichecchus manatus	Manatee	FL, GA, LA, MS, NC, SC, TX, VA
G3		
Antilope cervicapra	Blackbuck	TX[a]

G1 = critically imperiled; G2 = imperiled; G3 = vulnerable.
[a] Exotic.
Source: NatureServe 2000.

50 percent, from 23 million birds in 1975 to 12 million birds in 1993 (Flather and others 1999). Forest (ruffed) grouse populations show a cyclical pattern, but appear to have declined since 1985 (fig. 1.9).

Bobwhite quail trends from the Breeding Bird Survey (BBS) are consistent with State agency estimates (Flather and others 1999). BBS data suggest that the abundance of this species has declined significantly ($P < 0.05$) in the South. Bobwhite numbers have declined by 2.6 percent per year from 1966 to 1996, and have declined at an even greater rate since 1985 (-5.6 percent per year).

State agency projections for most small game species suggest minor changes in future population status. Forest grouse are expected to remain stable. State biologists forecast declines for bobwhite quail, squirrels, and cottontails.

Population and harvest trends for southern species: migratory game birds—Migratory game birds include waterfowl, such as ducks and geese, and other migratory species, such as mourning doves and woodcock. The long history of migratory bird management in North America has resulted in an impressive monitoring system. Population and harvest trends originate from annual reports published by the U.S. Fish and Wildlife Service and the North American Waterfowl Plan (Flather and others 1999).

Waterfowl trends are traditionally tracked by major flyways, which are the migration routes from breeding to wintering habitat. In the South, the major routes are the Atlantic and Mississippi flyways (fig. 1.10). National duck harvests have been recorded since the early 1960s.

Over the last 25 years, 41 percent of the national harvest was taken in the Mississippi flyway and 15 percent from the Atlantic flyway. Both had large harvests during the 1970s, followed by

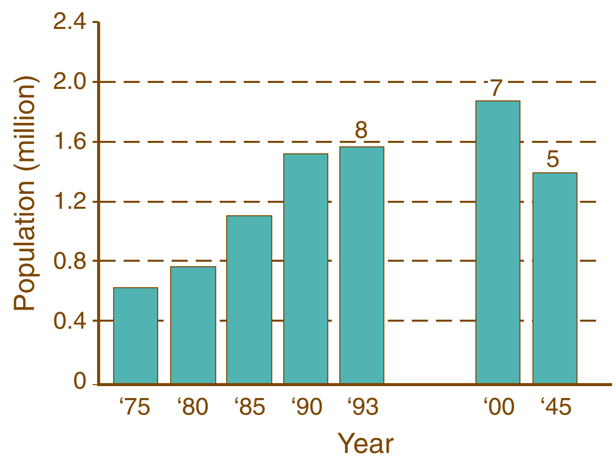


Figure 1.3—Population trends of wild turkey in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

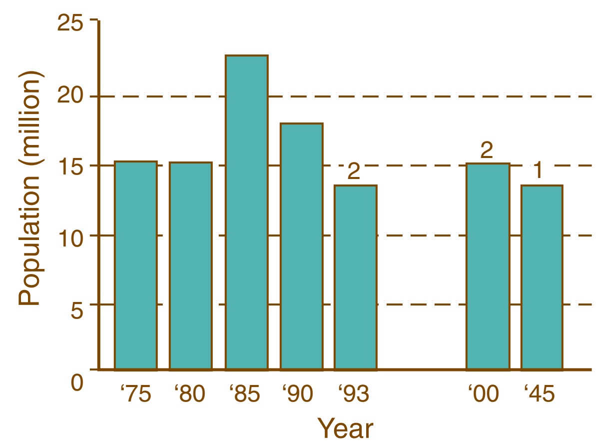


Figure 1.6—Population trends of red, gray, and fox squirrels in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

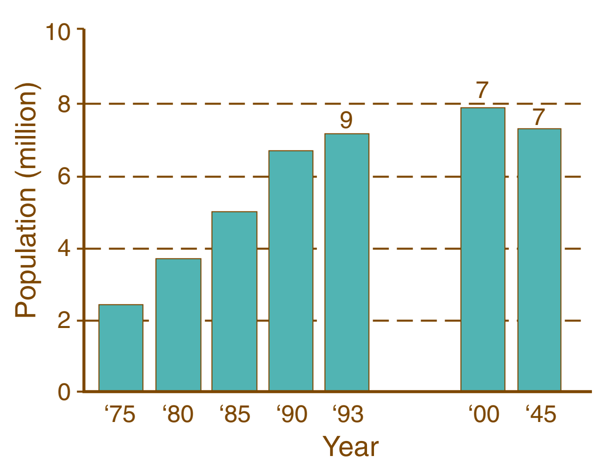


Figure 1.4—Population trends of deer in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

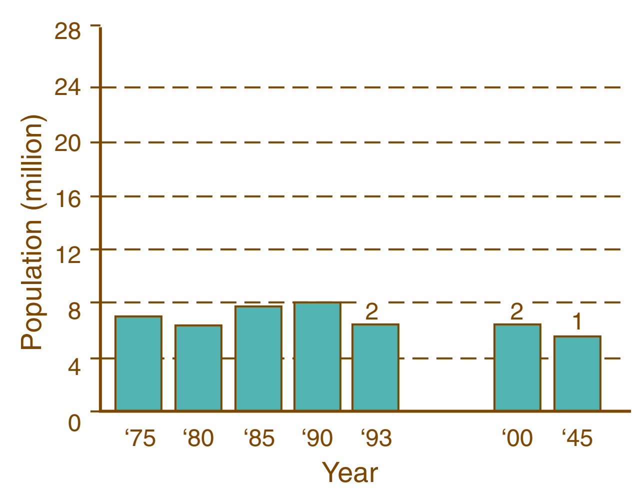


Figure 1.7—Population trends of cottontail rabbits in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

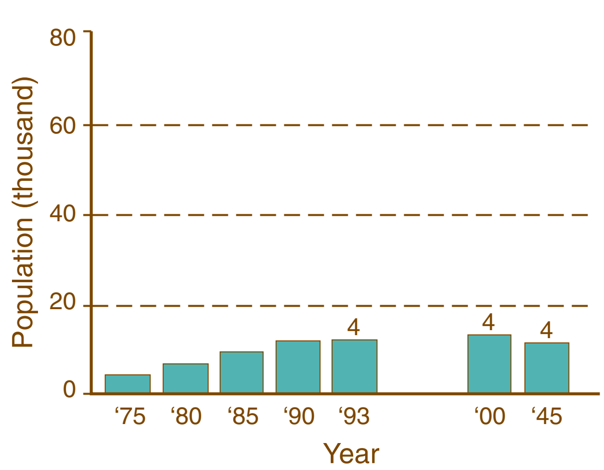


Figure 1.5—Population trends of black bear in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

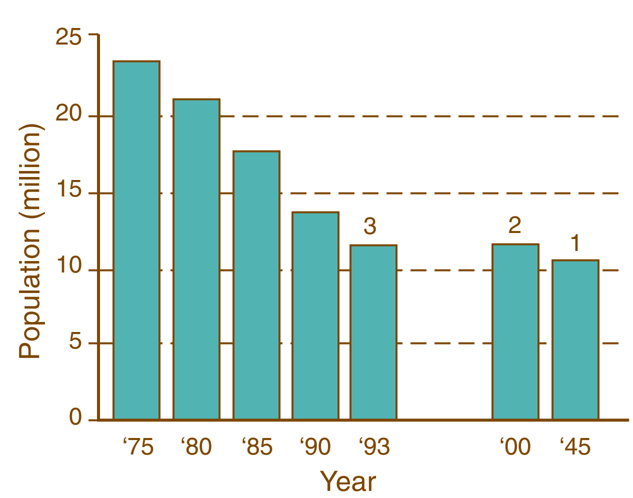


Figure 1.8—Population trends of northern bobwhite quail in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

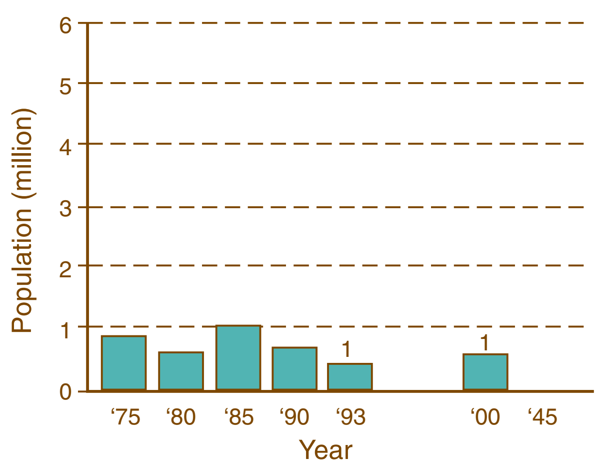


Figure 1.9—Population trends of forest grouse in Southern States that provided estimates and long-term projections [based on State wildlife agency data (Flather and others 1999)].

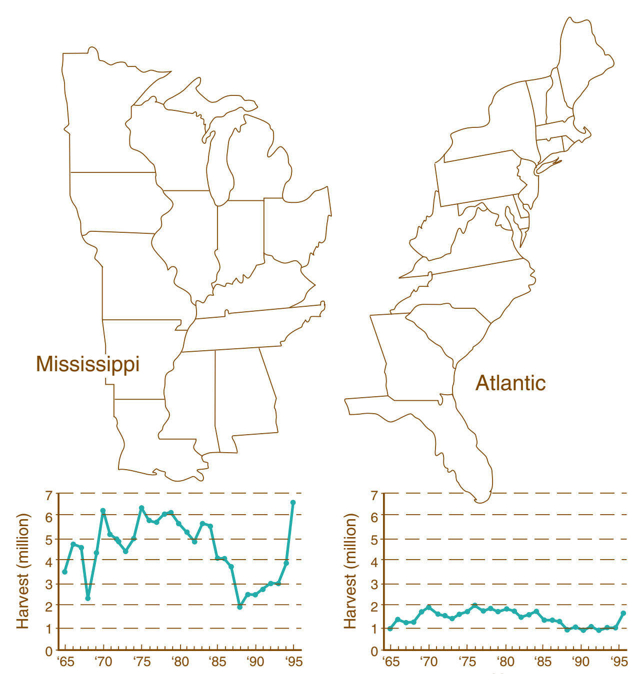


Figure 1.10—Trends in duck harvest from 1965 to 1995 by administrative flyway encompassing the South (Flather and others 1999).

substantial declines through much of the 1980s, and substantial harvest increases during the 1990s. Duck harvests in the Mississippi flyway increased by 260 percent from 1988 to 1995, with a record 6.6 million ducks harvested in 1995 (Flather and others 1999).

Trends in goose abundance were derived from surveys conducted in migration and wintering areas. Record numbers of geese were harvested for three consecutive years starting in 1993 along the Mississippi flyway (fig. 1.11). After reaching a peak harvest of about 550,000 birds in 1983, the goose harvest in the Atlantic flyway declined to nearly 180,000 birds in 1995.

Management units are traditionally used by agencies to report population trends of mourning doves and American woodcock. Both species are monitored using call-count surveys, which provide an index of population size. National trends in population indices for both species show evidence of declines, but the magnitude of the decline is greater for woodcock than for mourning doves. This pattern is confirmed by BBS data, which indicate

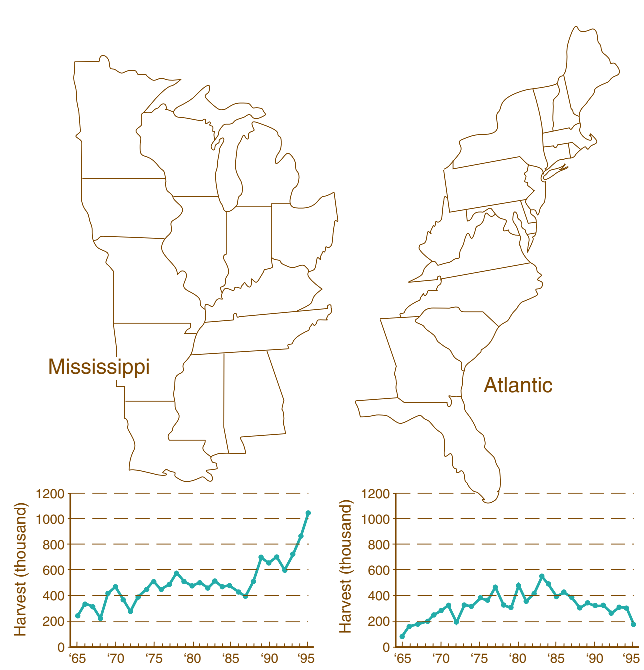


Figure 1.11—Trends in goose harvest from 1965 to 1995 by administrative flyway encompassing the South (Flather and others 1999).

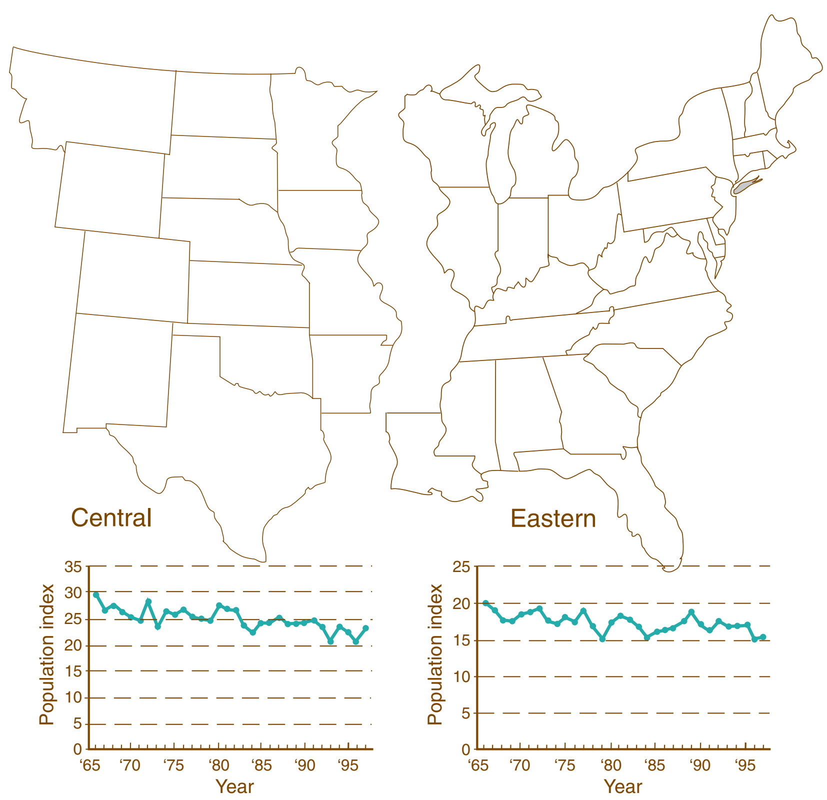


Figure 1.12—Population trends in mourning dove from 1966 to 1996 by management unit (Flather and others 1999).

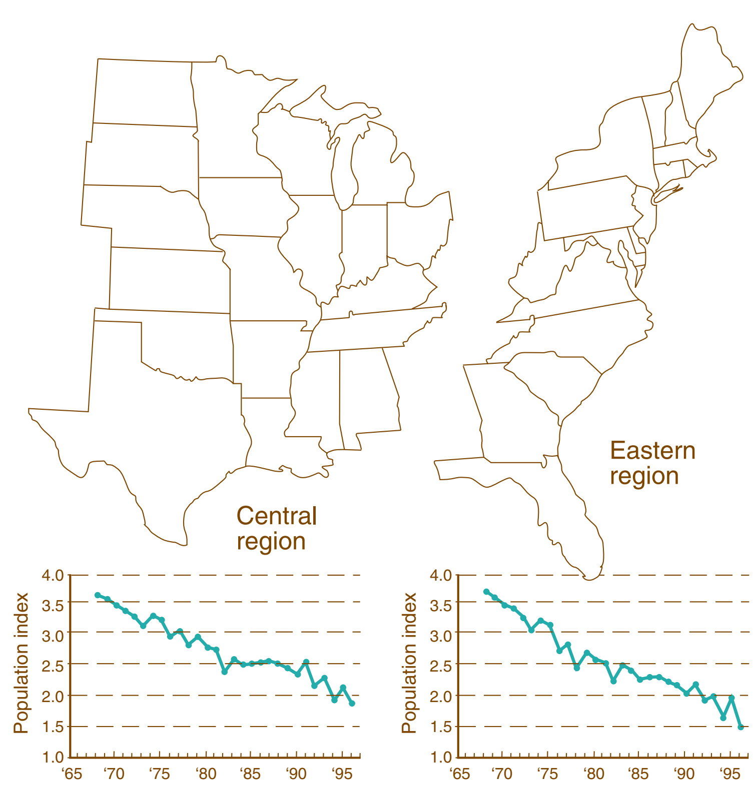


Figure 1.13—Population trends in woodcock from 1968 to 1996 by management unit (Flather and others 1999).

that doves declined annually at a rate of 0.3 percent compared to a 3.2 percent decline for woodcock over the 30-year period (Flather and others 1999).

Mourning dove calling counts indicate declining populations during the last 10 years in the eastern and central management units (fig. 1.12). Intensive agricultural practices may be influencing the breeding populations throughout much of the bird's range (Brady and others 1998). The acreage of agricultural land in the eastern management unit is positively related to dove populations because agricultural fields provide the forest edge habitat preferred by doves. Increased herbicide use and crop rotation may have contributed to observed declines (Martin and Sauer 1993). In the central management unit, the trend toward fewer and larger farms also may have influenced dove populations.

Call-count trends for woodcock show similar declines in both the eastern and central management units (fig. 1.13). Trends since 1968 indicate that the number of woodcock heard have declined by 2.5 percent per year in the eastern unit and 1.6 percent per year in the central unit (Flather and others 1999). In the last decade, this rate of decline has accelerated. Woodcock select early successional hardwood forests interspersed with fields and forest openings. As with the mourning dove, the widespread decline in woodcock may be linked with habitat alteration due to forest succession and land use intensification (Straw and others 1994).

Population and harvest trends for southern species: furbearer species—There are few comprehensive examinations of trends in furbearer populations nationwide. Often, the only available data are temporal harvest trends that reflect fur prices rather than population status. The limited information on population trends makes furbearer projections uncertain.

The RPA used a compilation of furbearer status reports completed for the International Association of Fish and Wildlife Agencies during 1993. A survey of State agency biologists provided population projections to 2003 (Southwick Associates. 1993. 1993 State and provincial survey of furbearers with emphasis on nuisance animals. Unpublished report. On file with:

Rocky Mountain Research Station, 2150 Center Avenue, Fort Collins, CO 80526).

Population projections of southern furbearers are shown in figs. 1.14, 1.15, 1.16, 1.17, 1.18, and 1.19. Of the 10 Southern States reporting beaver population projections, 5 expected population increases through 2003 (fig. 1.14). The beaver population is projected to decline in North Carolina, and remain stable (or increase) in the remainder of the South.

The majority of raccoon populations are projected to increase or remain stable throughout the South (fig. 1.15). Exceptions occur in Alabama and North Carolina, where disease-caused declines are projected (Flather and others 1999).

Of the four States reporting on muskrat populations, two expect population increases through 2003 (fig. 1.16). The remaining States (Virginia and Tennessee) project stable populations. Projections on coyote abundance are limited to Georgia and Mississippi (fig. 1.17). Both States report that coyote populations are expected to remain stable.

Bobcat projections are reported only for Florida and Oklahoma (fig. 1.18). Florida biologists report stable bobcat populations, while Oklahoma biologists report that bobcat populations are increasing. Finally, the five States that made projections for red and gray foxes (Virginia, Kentucky, Tennessee, South Carolina, and Texas) predicted stable populations (fig. 1.19).

Population and harvest trends for southern species: nongame birds— In the United States, nongame birds are not legally taken for sport, subsistence, or profit. Nongame species comprise the majority of taxa that inhabit the South. There are few data sources on populations of nongame species.

Data from the BBS were used to provide information on breeding bird trends in the South for the RPA. Details on the implementation of the BBS can be found in Droege (1990); information on statistical analyses can be found in Sauer and others (1997). The relative abundance trend for each bird species was summarized in two ways. First, the numbers of species with statistically significant increasing, decreasing, or stable trends were estimated. Second, birds were grouped according to life-history characteristics including nest

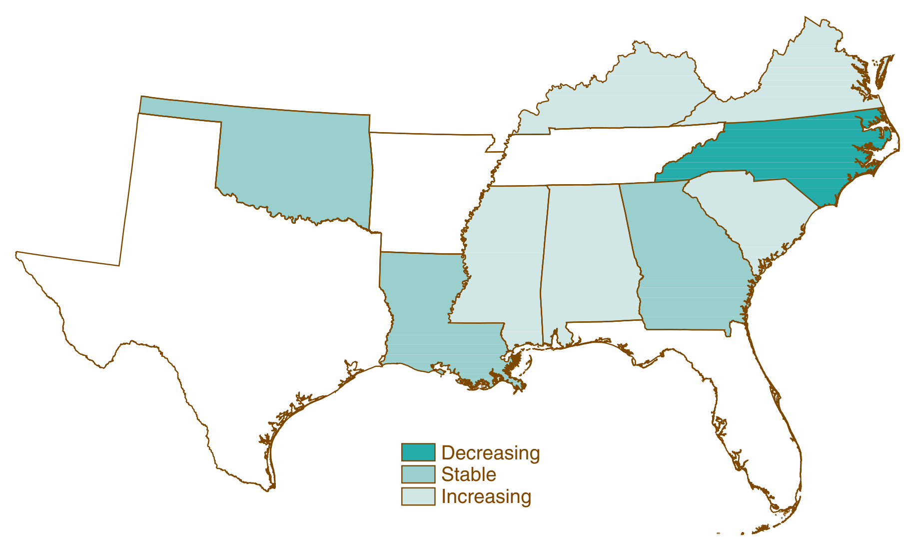


Figure 1.14—Projected trends of beaver populations in the South [based on State wildlife agency data (Flather and others 1999)]. States that provided estimates are shaded.

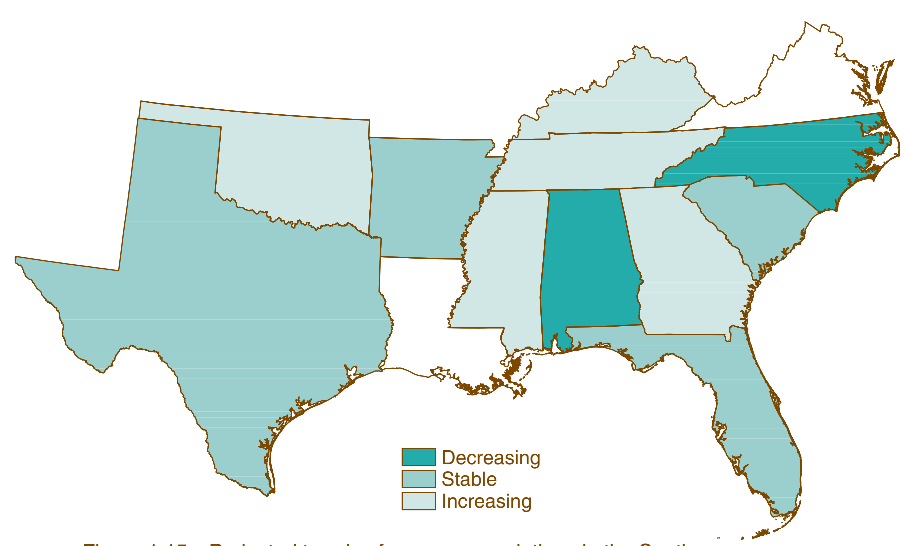


Figure 1.15—Projected trends of raccoon populations in the South [based on State wildlife agency data (Flather and others 1999)]. States that provided estimates are shaded.

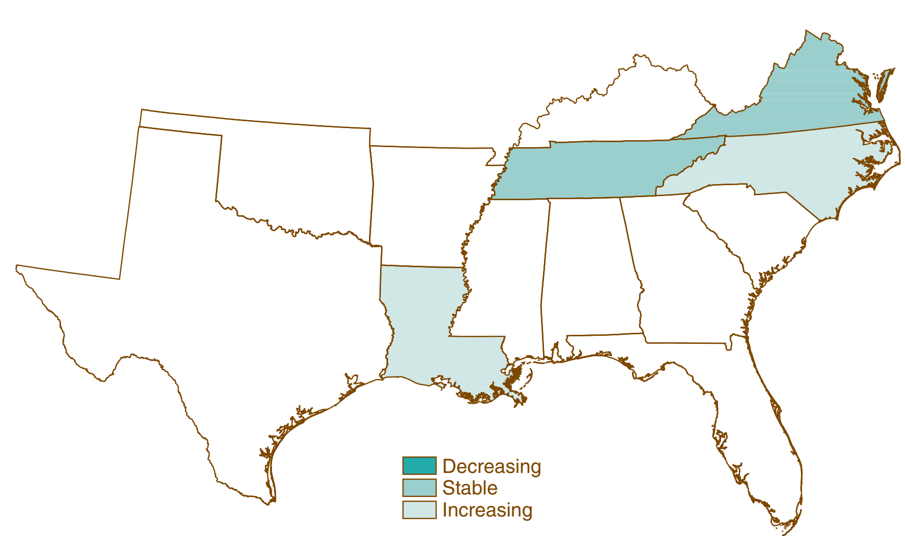


Figure 1.16—Projected trends of muskrat populations in the South [based on State wildlife agency data (Flather and others 1999)]. States that provided estimates are shaded.

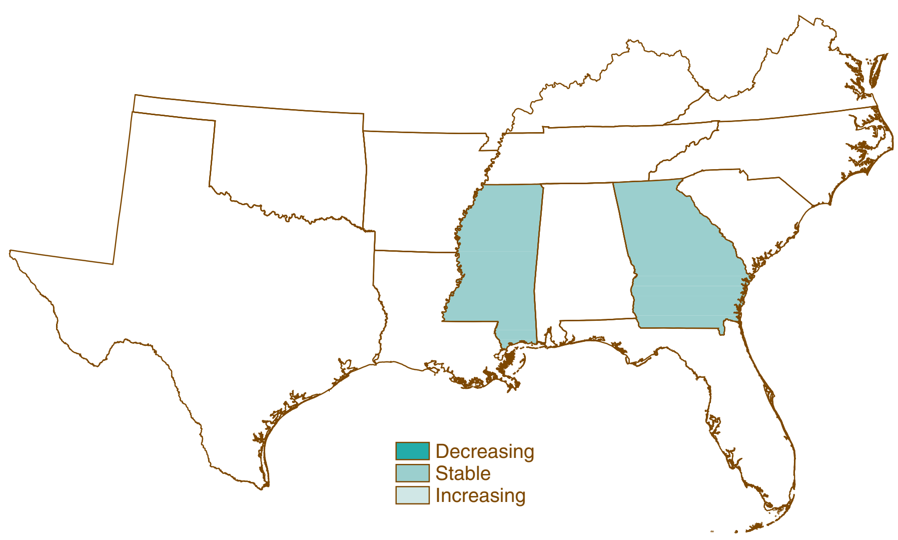


Figure 1.17—Projected trends of coyote populations in the South [based on State wildlife agency data (Flather and others 1999)]. States that provided estimates are shaded.

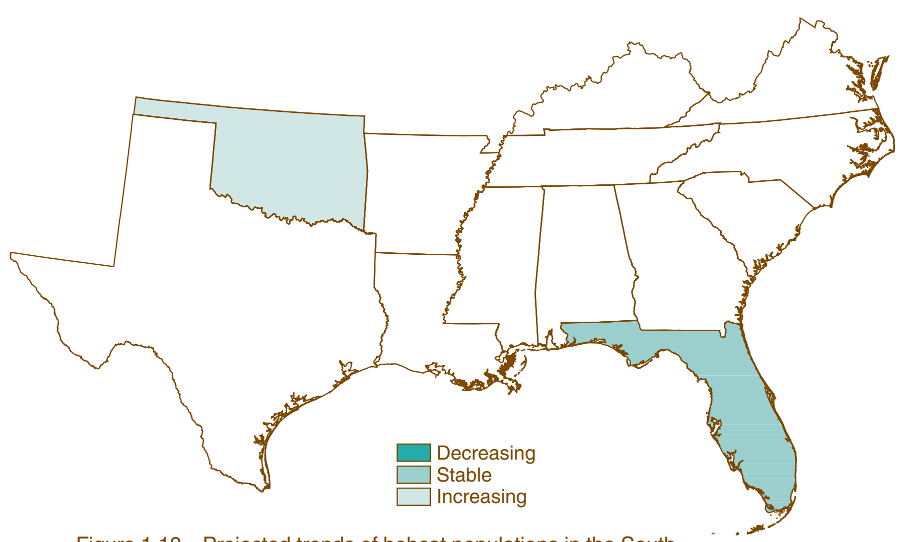


Figure 1.18—Projected trends of bobcat populations in the South [based on State wildlife agency data (Flather and others 1999)]. States that provided estimates are shaded.

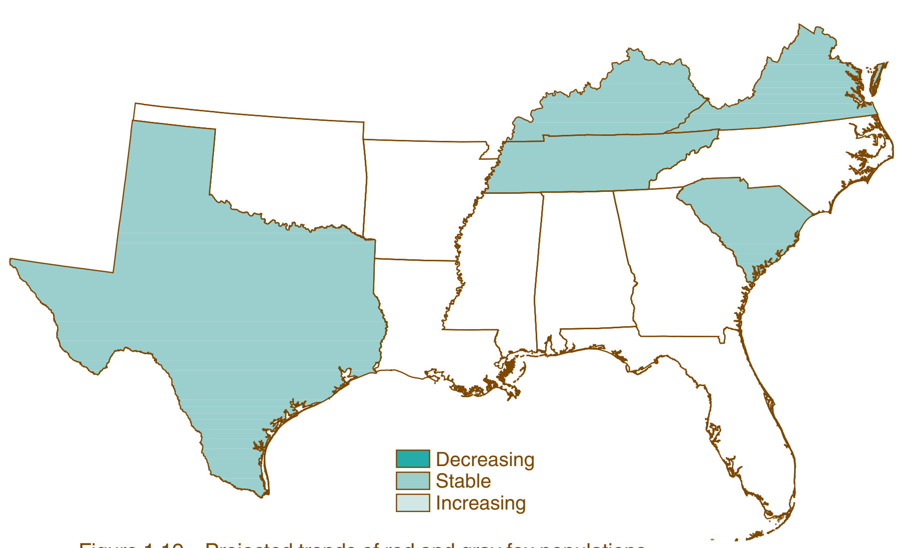


Figure 1.19—Projected trends of red and gray fox populations in the South [based on State wildlife agency data (Flather and others 1999)]. States that provided estimates are shaded.

type (cavity or open cup), nest location (ground, low, midstory, or canopy), migration status (neotropical migrant, short-distance migrant, permanent resident), and breeding habitat (woodland, shrubland, grassland, wetland, urban). The resulting trends are presented in figure 1.20.

Approximately 42.4 percent of breeding bird species appear stable, 35.2 percent have declined, and 22.4 percent have increased across the South (table 1.7). It is worth noting that Flather and others (1999) found that the percentage of declining species was greater in the South than in any other RPA region. Abundance trends among species groups vary considerably. Species with declining trends include 70 percent of grassland-nesting birds, 57 percent of ground-nesting birds, 53 percent of shrubland-nesting birds, 49 percent of open-cup nesting birds, 46 percent of urban-nesting birds, and 41 percent of neotropical migrants. Numbers of the majority of cavity-nesting species and wetland species have been stable.

Figure 1.21 suggests that bird species richness is high along the Southern Appalachians and along the Atlantic Coast from northeastern North Carolina to the Chesapeake Bay. Because some species are missed during bird count surveys including nocturnal species, raptors, and absent migrants, it is important to note that the bird richness estimates are biased low (Sauer and others 1997).

Raptors include hawks, falcons, eagles, vultures, and owls. In contrast to other bird species, raptors naturally exist at relatively low population densities and are widely dispersed in their habitats. The natural scarcity of raptors, their ability to move quickly, and the difficulties of detection inhibit the determination of population status (Fuller and others 1995).

As a group, raptors are poorly surveyed, and quantitative data are lacking to determine their population trends. Table 1.8 presents a national summary of the status and population trends of 33 species and subspecies of southern raptors. Two species, the American kestrel and burrowing owl, are declining across the United States. Mississippi kites, osprey, bald eagles, and peregrine falcons are increasing. Populations of 22 species are considered stable nationwide.

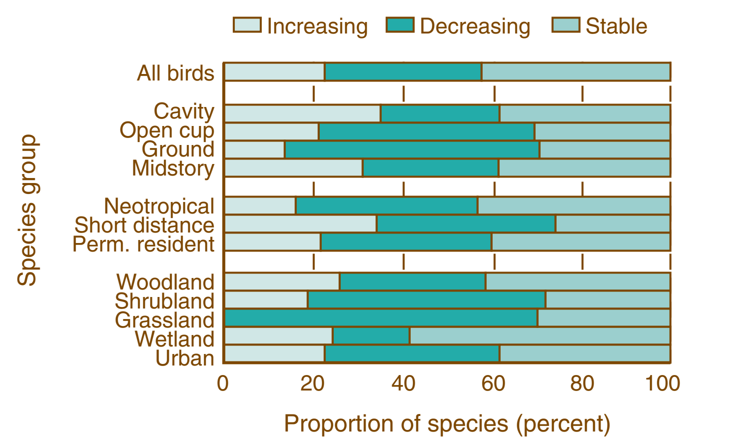


Figure 1.20—The proportion of southern bird species with increasing, decreasing, and stable trends from 1966 to 1996. Birds have been grouped by broad life-history characteristics, migration status, and breeding habitat (Flather and others 1999).

Table 1.7—Number of breeding bird species with increasing, decreasing, and stable trends from 1966 to 1996 by life history characteristics for the South

Life history characteristic	Total species	Increasing species	Decreasing species	Stable species
	N		*N (Percent)*	
All species	210	47 (22.4)	74 (35.2)	89 (42.4)
Nest type/location				
Cavity	29	10 (34.5)	8 (27.6)	11 (37.9)
Open cup	86	18 (20.9)	42 (48.8)	26 (30.2)
Ground/low	54	7 (13.0)	31 (57.4)	16 (29.6)
Midstory/canopy	65	20 (30.8)	20 (30.8)	25 (38.5)
Migration status				
Neotropical	76	12 (15.8)	31 (40.8)	33 (43.4)
Short distance	50	17 (34.0)	20 (40.0)	13 (26.0)
Permanent resident	42	9 (21.4)	16 (38.1)	17 (40.5)
Breeding habitat				
Woodland	58	15 (25.9)	19 (32.8)	24 (41.4)
Shrubland	43	8 (18.6)	13 (53.5)	12 (27.9)
Grassland	10		7 (70.0)	3 (30.0)
Wetland/open water	46	11 (23.9)	8 (17.4)	27 (58.7)
Urban	13	2 (15.4)	6 (46.2)	5 (38.5)

Source: Flather and others 1999.

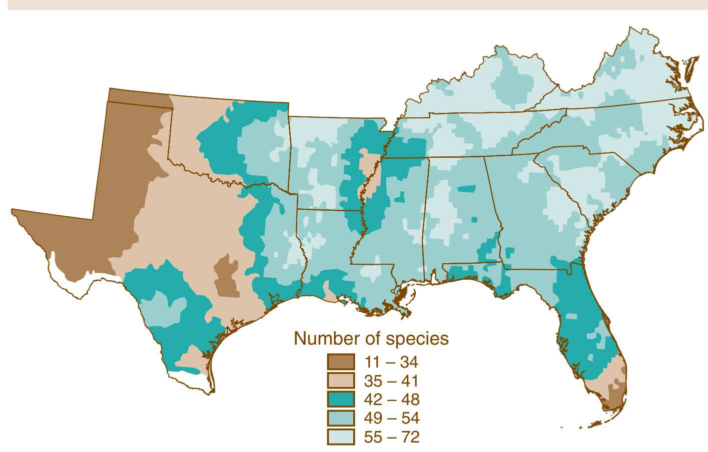


Figure 1.21—Patterns of bird richness in the South based upon counts from the Breeding Bird Survey (Flather and others 1999).

Table 1.8—The national trends of raptors that occur in the South

Scientific name	Common name	Status/Trend/Comments
Accipiter cooperii	Cooper's hawk	Stable
Accipiter gentilis	Northern goshawk	Unknown/C2[a]
Accipiter striatus	Sharp-shinned hawk	Stable/regional differences
Aquila chrysaetos	Golden eagle	Stable
Asio acadicus	Northern saw-whet owl	Stable
Asio flammeus	Short-eared owl	Stable/local concern
Asio otus	Long-eared owl	Stable/local concern
Athene cunicularia	Burrowing owl	Declining/local concern
Bubo virginianus	Great horned owl	Stable
Buteo brachyurus	Short-tailed hawk	Stable/northern range limit, about <500 birds in U.S.
Buteo lagopus	Rough-legged hawk	Stable
Buteo lineatus	Red-shouldered hawk	Stable/local concern
Buteo jamaicensis	Red-tailed hawk	Stable/local increases; Breeding Bird Survey data
Buteo platypterus	Broad-winged hawk	Stable/migration count decline in 1980s
Buteo regalis	Ferruginous hawk	Unknown/C2
Buteo swainsoni	Swainson's hawk	Unknown/C3;[b] local concern
Caracara plancus	Crested caracara	Unknown/northern range limit
Cathartes aura	Turkey vulture	Stable
Circus cyaneus	Northern harrier	Stable/nomadic, no standard survey; local concern
Coragyps atratus	Black vulture	Stable/population estimation difficult
Elanoides forficatus	American swallow-tailed kite	Stable/historical range
Falco columbarius	Merlin	Stable
Falco peregrinus anatum	American peregrine falcon	Endangered; increasing
Falco sparverius	American kestrel	Stable/Breeding Bird Survey Data
Falco sparverius paulus	American kestrel, Florida	Declining/C2
Haliaeetus leucocephalus	Bald eagle	Threatened or endangered in contiguous U.S.; increasing/status reassessment underway
Ictinia mississippiensis	Mississippi kite	Increasing/range expansion
Nyctea scandiaca	Snowy owl	Stable
Otus asio	Eastern screech-owl	Stable
Pandion haliaetus	Osprey	Increasing/good information
Rostrhamus sociabilis	Snail kite	Endangered, stable/northern range limit
Strix varia	Barred owl	Stable/western range expansion
Tyto alba	Common barn owl	Stable/local concern

[a] Proposal to list; available data are not conclusive for threatened or endangered status.
[b] Proven more widespread than previously believed or not subject to identifiable threat.
Source: Fuller and others 1995.

The status of a raptor population often reflects changes in the availability of prey species. However, changes in raptor status also can indicate subtle environmental conditions, such as chemical contamination or disease.

Nesting ospreys are concentrated along the Atlantic Coast. Most regional populations declined through the early 1970s. Following the nationwide ban on DDT in 1972, osprey productivity improved, and population numbers increased in many areas. Osprey numbers are stable, and in some areas they are increasing.

The endangered snail kite breeds in central and southern Florida wetlands, the northern extent of the range. The species declined from 1900 to 1960. Populations remain relatively stable today.

Bald eagle populations declined dramatically between 1950 and 1970. Illegal shooting, habitat alteration, and DDT adversely affected bird populations. The species was classified as endangered in 1978. Following the DDT ban, bald eagle reproduction improved, and populations began increasing. The active protection of nesting habitat and release of hand-reared eagles aided this increase. Habitat loss remains a threat in many areas (Fuller and others 1995).

Ferruginous hawk populations are stable in some areas, but declining in others. Status determination is complicated by the low density of nesting birds and fluctuation in breeding associated with cycles of prey abundance.

The peregrine falcon also suffered from contamination by DDT and other organochlorine pesticides. Peregrine recovery has been hastened in the East by the release of hundreds of birds bred in captivity; these birds survived and produced young in the wild.

Sensitive and Rare Communities

Extent of threatened communities—Several authors have described and identified the threatened and sensitive communities in the South (Boyce and Martin 1993, Grossman and others 1994, Noss and others 1995, White and others 1998). The South supports a diversity of communities; a high proportion of them are considered imperiled to some degree (Walker 2001).

Noss and others (1995) listed numerous threatened and endangered communities that have experienced losses in the South (table 1.9). The amount of areal loss relative to the estimated presettlement area was used as an indicator of vulnerability. The 14 communities listed as critically endangered have estimated losses of over 98 percent of their area since European settlement. These include old-growth deciduous forest, spruce-fir forests, longleaf pine savannas, bottomland forest, and several types of prairies. Twenty-five endangered communities have experienced losses between 85 and 98 percent. These communities include Coastal Plain hardwoods, pocosins, mountain bogs, ultramafic glades, and Louisiana prairies.

Having experienced over 70 percent losses compared to estimated presettlement area, 11 communities are regarded as threatened. These include tropical hardwood hammocks, sandhill woodlands, and saline prairies.

In addition to the list in table 1.9, Noss and others (1995) reported 24 communities that have lost at least 50 percent of their area. These include pocosins (Coastal Plain), sand pine (Florida), baldcypress-tupelo (Mississippi, Tennessee), flatwoods-swale habitats (Florida), herbaceous marsh (Florida), calcareous forest (Louisiana), scrub-shrub swamp (Louisiana), cove hardwood forest (Tennessee), and others.

Boyce and Martin (1993) also recognized several sensitive communities that are under pressure from a variety of factors. Such factors included

Table 1.9—Ecosystem communities that have declined by 70 percent or more in the South since European settlement

Ecosystem type	Geographic area
Critically endangered: >98 percent loss	
Old-growth deciduous forests	Southeast
Southern Appalachian spruce-fir	Tennessee, North Carolina, Virginia
Longleaf pine forests and savannas	Southeastern Coastal Plain
Slash pine and rockland habitat	Southern Florida
Loblolly-shortleaf pine forests	West Gulf Coastal Plain
Canebrakes	Southeast
Bluegrass savannah-woodland and prairies	Kentucky
Black Belt and Jackson prairies	Alabama, Mississippi
Ungrazed dry prairie	Florida
Wet and mesic coastal prairies	Louisiana
Atlantic white-cedar	Virginia, North Carolina
Native prairies	Kentucky
Bottomland forest	West Virginia
High-quality oak-hickory	Cumberland Plateau, Tennessee
Endangered: 85-98 percent loss	
Red spruce	Central Appalachians
Spruce-fir forest	West Virginia
Upland hardwoods	Coastal Plain, Tennessee
Old-growth oak-hickory	Tennessee
Cedar glades	Tennessee
Longleaf pine	Texas, Louisiana
Longleaf pine forest, 1936-87	Florida
Mississippi terrace prairie, calcareous prairie, Fleming glades	Louisiana
Live oak, live oak-hickory	Louisiana
Prairie terrace-loess oak forest	Louisiana
Mature forest, all types	Louisiana
Shortleaf pine-oak-hickory	Louisiana
Mixed hardwood-loblolly pine	Louisiana
Xeric sandhill	Louisiana
Stream terrace-sandy wooded-savannah	Louisiana
Slash pine	Florida
Gulf Coast pitcher-plant bogs	Coastal Plain
Pocosins	Virginia
Mountain bogs	North Carolina
Appalachian bogs	Blue Ridge, Tennessee
Upland wetlands	Highland Rim, Tennessee
Ultramafic glades	Virginia
Threatened: 70-84 percent loss	
Bottomland and riparian forest	Southeast
Xeric scrub, scrubby flatwoods, sandhills	Lake Wales Ridge, Florida
Tropical hardwood hammock	Florida Keys
Saline prairie	Louisiana
Upland longleaf pine	Louisiana
Live oak-pine-magnolia	Louisiana
Spruce pine-hardwood flatwoods	Louisiana
Xeric sandhill woodlands	Louisiana
Flatwood ponds	Louisiana
Slash pine-pondcypress-hardwood	Louisiana
Wet hardwood-loblolly pine	Louisiana

Source: Noss and others 1995. Based on the published literature, Natural Heritage programs, and expert opinion.

Table 1.10—The Nature Conservancy's summary of distributions and threats for rare communities of the South

Geographic area	Habitat	Number of communities	Threats
Southern Appalachian Mountains	Spruce-fir	2	Nonindigenous species, recreation, air pollution, past logging, hydrological alteration, succession.
	Beech	2	
	Bog, fen	7	
	Grassy bald	1	
	Cliff, gorge	4	
	Other	1	
South Florida	Tropical hardwood	2	Development, nonindigenous species, hydrological alteration, fire suppression, burning, fragmentation, agriculture, recreation.
	Slash pine	3	
Coastal Plain	Barrier island	9	Development, grazing, fragmentation, hydrological alteration, fire suppression, nonindigenous species, agriculture, past logging, mining, burning, recreation.
	Longleaf pine	3	
	Other forests	3	
	Glade, prairie	6	
Continental Interior	Forest	7	Fire suppression, agriculture, recreation, grazing, past logging, nonindigenous species, succession, mining, hydrological alteration.
	Glade, prairie	3	
	Other	1	
Other	Outcrop	1	Recreation, grazing, agriculture, hydrological alteration, fire suppression.
	Forest	1	
	Canebrake	1	

Source: Grossman and others 1994.

urban growth, land use conversion, water diversion, exotic species, and pesticide runoff. Everglades, mangroves, bottomland hardwood forests, pocosins, mountain bogs, and Carolina bays were classified as threatened. They classified longleaf pine, spruce-fir and other high-elevation forests, heath balds, maritime communities, rock outcrops, glades, grasslands, and sand-pine scrub as vulnerable.

Grossman and others (1994) listed 57 rare communities in the South (table 1.10). Community types were ranked on a global scale based on the number of occurrences, areal extent, condition, threats, and fragility. These 57 communities had global ranks of G1 (found in 1 to 5 occurrences globally) or G2 (found in 6 to 10 occurrences globally). Twenty-one types occur in the Coastal Plain, 5 in south Florida, 17 in the Southern Appalachians, and 11 in the Continental Interior.

Communities can decline in areal extent or have their structures impoverished or compromised. Communities covering smaller areas tend to maintain smaller populations that are more vulnerable to extinction than larger populations (Soulé 1987). Communities also can lose vigor because of change in their structure, function, or composition. For example, intense livestock grazing entails replacement of native perennial grasses with exotic annuals. The factors contributing to community imperilment that are listed in table 1.10 are further discussed in the following section.

Profiles of selected rare communities—This section reviews some selected communities of concern. Each general community type can include multiple associations. Each account includes distribution, composition, threats, and potential management. Where available, steps toward restoration are presented. The accounts were developed from White and others (1998), Boyce and Martin (1993), Noss and others (1995), and Walker (2001). The discussion of communities follows White and others (1998).

Profiles of selected rare communities: old-growth forests—Although forests predominate in the South, less than 585,790 acres of old-growth forest exist (White and others 1998). The remaining old-growth forests tend to be on steeper, rockier, or mesic sites difficult to farm or harvest. Old-growth forest composition varies with forest type, but characteristics generally associated with old-growth forests include large, old trees; accumulations of woody debris; and multilayered canopies.

Many vertebrate species occur in patches of old-growth forest. These include the Jefferson salamander, the Peaks of Otter salamander, the oak toad, and the scarlet king snake (Wilson 1995). Public lands such as the Great Smoky Mountains National Park and several national forests protect some of the largest tracts in the South. With the exception of these areas, old-growth remnants are often smaller than 250 acres.

Threats to old-growth remnants include invasions by nonindigenous species, interruption of natural disturbance regimes, outbreaks of forest pests, and timber harvest (Walker 2001).

Management options vary by forest type, but controlling nonindigenous species and herbivores, and choosing benign methods to accomplish these objectives are factors to consider. Management actions that mimic natural disturbances are particularly important because natural disturbance regimes are unlikely to be intact. Management emphasis may also include the provision of forested buffers around existing old-growth remnants.

Profiles of selected rare communities: spruce-fir forests—The spruce-fir community is confined to the highest peaks of Virginia, Tennessee, and North Carolina. Red spruce communities occur at an approximate elevation of 4,500 feet. In the northern limit of its range, Fraser fir is replaced with balsam fir. This community is characterized by relatively high moisture levels, short growing seasons, acidic soils, and extreme weather conditions. The flora is distinctive. The community reproduces in small-scale patches resulting from wind disturbance.

The presettlement extent of the Southern Appalachian spruce-fir community has been estimated as 30,000 to 35,000 acres (White and others 1998). These remote forests remained relatively undisturbed until the widespread harvests of the late 1800s (White and others 1998). In 1934, the majority of the remaining spruce-fir forest went into public protection with the establishment of the Great Smoky Mountains National Park.

Spruce-fir communities are threatened by infestations of balsam woolly adelgids. The stresses induced by insect attack are exacerbated by additional stresses of acid precipitation, which influence soil and stream chemistry. Air pollution and the deposition of heavy metals, such as lead, copper, zinc, nickel, and manganese, also contribute to the decline of this community (refer to chapter 18). They inhibit regeneration and contaminate the understory. Airborne pollution is carried with prevailing winds originating from industrial areas of southern Ohio and Indiana.

In addition, recreation activities compact soil and damage young trees. As the southern population centers expand, continued recreational pressure may further adversely affect the spruce-fir community.

Spruce-fir communities support several terrestrial species that are uncommon elsewhere. Examples include the endangered subspecies of northern flying squirrel, Weller's salamander, the endangered spruce-fir moss spider, mountain ash, and the threatened rock gnome lichen. The northern saw-whet owl, black-capped chickadee, and red crossbill also inhabit the community.

Restoration centers on enhancing the stocking of red spruce trees and increasing stand structural complexity. Appropriate silvicultural treatments include the release of spruce saplings from the understory and the removal of competing stems. In some areas, restoration may involve conversion of open areas to forests by planting seedlings.

Profiles of selected rare communities: wetlands, bog complexes, pocosins—In the last two centuries, the Nation has lost approximately 30 percent of its wetlands. Substantial losses have occurred along the southern Coastal Plain and along the lower reaches of the Mississippi River. In addition, Florida has lost 46 percent (9 million acres) of its wetlands (Stein and others 2000). Wetland loss is of special concern, because these habitats provide critical waterfowl and fish habitat.

Small wetlands occur in depressions embedded in forested areas. Soils are saturated for extended periods from rainfall and ground water seepage. Among the most vulnerable areas are small (less than 2 acres), isolated bogs that retain characteristic species. Bogs require distinct hydrological conditions to function ecologically. Intermittent fires and beaver activities may contribute to the origin and maintenance of this complex.

The exact number of remaining bogs is difficult to determine but is most certainly fewer than 150 in the entire South. Over half of the existing bogs occur on private land, and are threatened by development, grazing, off-road vehicle use, agricultural practices, and hydrological alteration.

Pocosins are freshwater wetlands dominated by a dense cover of broad-leaved evergreen shrubs or low-growing trees. They have highly organic soils that developed in areas of poor drainage. This community occurs in upland interstream areas. Peat layers are thick, and vegetation is shrubby.

The bog complex provides habitat for a diversity of herpetofauna. Wilson (1995) lists 37 species of reptiles and amphibians associated with Carolina bays, pocosins, and bogs in the South; 41 are associated with swamp habitat. These species include the bullfrog, green frog, eastern tiger salamander, four-toed salamander, mountain chorus frog, and snapping turtle. The bog turtle, threatened in the northern portion of its range, also inhabits these areas. This turtle is collected illegally, as are rare orchids and carnivorous plants. Opportunities for species to recolonize are minimal, and the community is permanently diminished.

Avian species occurring in these communities include cedar waxwing, Nashville warbler, northern water-thrush, purple finch, white-eyed vireo, and wood duck. Characteristic mammals include the long-tailed shrew, marsh rice rat, mink, muskrat, river otter, southern bog lemming, southern short-tailed shrew, and the star-nosed mole. Butterflies include the Atlantis fritillary and silver-bordered fritillary.

No vertebrates are endemic to pocosins, but the community provides habitat and refuge from adjacent landscape development. In North Carolina, 41 species of mammals inhabit pocosin and Carolina bay sites (White and others 1998).

Conservation activities include protection from heavy equipment, off-road vehicles, and foot traffic; controlling changes in site hydrology by providing buffers between adjacent sites, filling ditches and blocking drains; and restricting livestock grazing. The retention of woody debris provides valuable microhabitat for many species. Adjacent land management activities that alter the surrounding watershed degrade these sensitive communities. Restoration includes maintenance of site hydrology and woody plant control. Periodic prescribed burns adjusted to maintain vegetative conditions help to maintain the community. Species reintroduction into selected sites also may be required.

Profiles of selected rare communities: bottomland and floodplain forests—The forested wetlands of the Coastal Plain, Piedmont, and Continental Interior Provinces include bottomland hardwood forests and deepwater alluvial swamps. Bottomland hardwoods are located along waterways and in low-lying areas such as the Mississippi Delta region. Common tree species include ash, sycamore, water tupelo, cypress, willow, cottonwood, elm, oaks, river birch, silver maple, sweetgum, black walnut, and pine. Vegetative composition and structure vary with flooding duration. Trees are vulnerable to prolonged changes in hydrology and are characterized by rapid growth. Bottomland hardwoods are found almost exclusively on alluvial soils that are associated with old riverbeds, existing streams, and impoundments and their terraces. Soils are saturated year round or nearly so; the understory is sparse with vines and shrubby vegetation.

Beneficial characteristics of this community for wildlife include hard mast production, cavity tree provision, and production of abundant invertebrate biomass. In agricultural landscapes, bottomland forests serve as refuges for many species. Species associated with this community include wood stork, prothonotory warbler, marbled salamander, and the swamp rabbit. The loss of bottomland hardwood forests to agricultural conversion contributed to the decline of the Carolina parakeet and the ivory-billed woodpecker (Dickson 2001).

Many bottomland sites are productive and have been in agricultural production for long periods. Several cypress-oak reforestation projects in the Mississippi Alluvial Valley have been successful in areas where frequent flooding precludes agricultural development. Restoration of this community occurs primarily on public land.

Profiles of selected rare communities: glades, barrens, and prairies—Scattered throughout the South are naturally treeless areas referred to as prairies, glades, and barrens. Historical accounts suggest that these open communities were once widespread (Delcourt and others 1993), but estimates of original extent are uncertain. These grass-dominated communities occurred in the Piedmont, Interior Plateau, Ridge and Valley, and Coastal Plain Provinces.

Lightning fires, Native American burning, grazing by elk and bison, and soil conditions historically maintained these areas. Today, these communities occupy only a fraction of their original extent due to agricultural conversion, recreation use, exotic species invasions, fire exclusion, and the loss of large herbivores.

Forbs and grasses occurring on rocky or shallow soil dominate glades; composition varies with geology, soil type, and soil depth (Walker 2001). The limestone glades of the Ozarks, dominated by perennial grasses, have a more open nature than glades of the Interior Low Plateau. Eastern redcedar woodlands are commonly associated with glades of various types. Threats to glade communities include construction, quarrying, agriculture (pasture), fire suppression, and nonindigenous species invasion.

The barren and prairie communities contain the majority of the region's native grasslands. In the South, they include the Black, Jackson, and Grand Prairies. In these communities, grasses are dominant, and shrubs and trees are generally absent. The sites are highly productive because they retain nutrients. As a result, they support a vast array of animal and plant life.

Species composition varies with site moisture. Characteristic species include little bluestem, Indian grass, and big bluestem. Composition varies depending upon specific soil and geologic types.

The size and isolation of these open areas preclude support of endemic vertebrates. Many rare species of birds, reptiles, and arthropods use these communities. Vertebrate species that have been extirpated from these communities include the greater prairie chicken, bison, and elk.

Restoration centers on the control of woody species from adjacent forest habitats and the use of prescribed burning to maintain the diversity of the grassland communities. The retention of characteristic species relies upon site-specific management.

Profiles of selected rare communities: longleaf pine and southern pinelands—Longleaf pine historically dominated Coastal Plain sites from southern Virginia to eastern Texas. It also occurred on sites in the Piedmont, southern Ridge and Valley, and southern Blue Ridge Provinces (fig. 1.22). This community once covered over 40 percent of the entire region, but it has declined by more than 98 percent (Noss and others 1995).

The community came under pressure during the mid-17th century. Demand began for naval stores and then turned

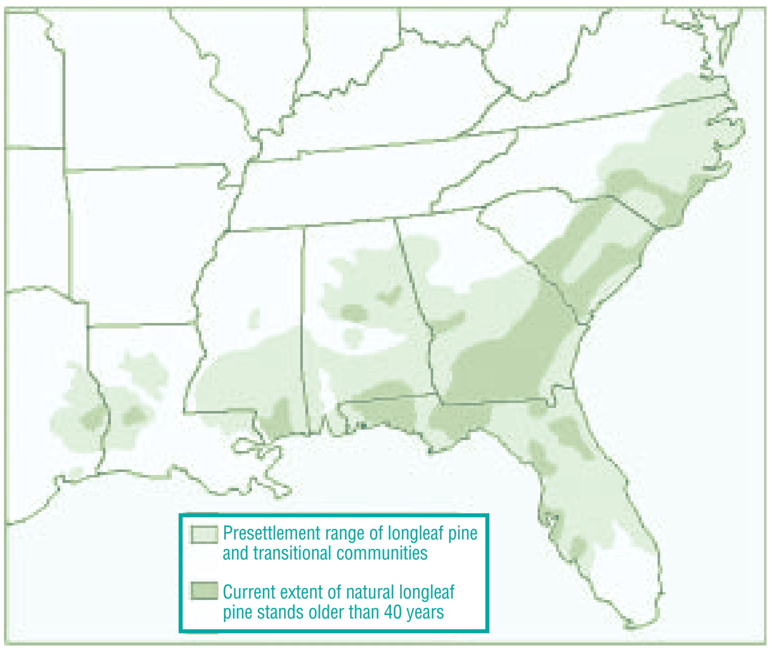


Figure 1.22—The historic and present distribution of longleaf pine in the South (White and others 1998).

to timber needs. By the 1960s, extensive areas were harvested and converted to commercial plantations of loblolly and slash pine. Fire suppression and the introduction of livestock further restricted the longleaf community to a few isolated locations comprising about 5 million acres. At present, the majority occurs on private land. Much of what remains is largely degraded due to lack of proper management.

Community composition varies with soil moisture and geography. Wiregrass and bluestem dominate the herbaceous layer. This herb layer is diverse and includes grasses, wildflowers, and carnivorous plants. In mature communities, the trees are thinly distributed and flat-topped, and have limbless lower trunks.

The community harbors several vertebrate species. The fox squirrel is a long-lived species with low reproductive rates. It depends on longleaf pine for late summer forage. The decline in longleaf communities

Table 1.11—Examples of soft and hard mast-producing species in the South

Scientific name	Common name	Scientific name	Common name
Soft mast		Berries	
Pomes		*Diospyros virginiana*	Common persimmon
Amelanchier spp.	Serviceberries	*Juniperus virginiana*	Eastern redcedar
Crataegus spp.	Hawthorn	*Lonicera japonica*	Japanese honeysuckle
Pyrus malus	Common apple	*Smilax spp.*	Greenbriers
Drupes		*Vaccinium spp.*	Blueberries
Berchemia scandens	Alabama supplejack	*Vitis aestivalis*	Muscadine grape
Callicarpa Americana	American beautyberry	*Vitis rotundifolia*	Summer grape
Celtis occidentalis	Hackberry	Hard mast	
Cornus florida	Flowering dogwood	Nuts	
Gaylussacia spp.	Huckleberries	*Aesculus octandra*	Yellow buckeye
Gaylussacia dumosa	Dwarf huckleberry	*Carpinus caroliniana*	American hornbeam
Ilex spp.	Hollies	*Carya spp.*	Hickories
Ilex cassine	Dahoon	*Carya aquatica*	Water hickory
Ilex coriacea	Large gallberry	*Carya cordiformis*	Bitternut
Ilex deciduas	Possumhaw	*Carya glabra*	Pignut
Ilex glabra	Gallberry	*Carya ovata*	Shagbark
Ilex myrtifolia	Myrtle dahoon	*Carya tomentosa*	Mockernut
Ilex opaca	American holly	*Castanea spp.*	Chinkapin
Ilex vomitoria	Yaupon	*Fagus grandifolia*	American beech
Morus rubra	Red mulberry	*Juglans cinera*	Butternut (white walnut)
Myrica cerifera	Southern bayberry		
Myrcia pensylvanica	Northern bayberry	*Juglans nigra*	Black walnut
Nyssa aquatica	Water tupelo	*Ostrya virginiana*	Eastern hophornbeam
Nyssa sylvatica	Black tupelo and Swamp tupelo	*Nyssa sylvatica*	Black gum
		Quercus spp.	Oaks
Persea borbonia	Redbay	*Quercus alba*	White oak
Prunus serotina	Black cherry	*Quercus chapmanii*	Chapman oak
Prunus spp.	Wild cherries and plums	*Quercus michauxii*	Swamp chestnut oak
		Quercus prinus	Chestnut oak
Rhus copallina	Shining sumac	*Quercus stellata*	Post oak
Rhus glabra	Smooth sumac	*Quercus virginiana*	Live oak
Rhus radicans	Common poison ivy	*Quercus falcate*	Southern red oak
Rhus typhina	Staghorn sumac	*Quercus ilicifolia*	Bear oak
Rubus spp.	Blackberries	*Quercus incana*	Bluejack oak
Sabal spp.	Palmetto	*Quercus laurifolia*	Laurel oak
Sambucus canadensis	American elder	*Quercus marilandica*	Blackjack oak
Sassafras albidum	Sassafras	*Quercus nigra*	Water oak
Serenoa repens	Saw-palmetto	*Quercus nuttalli*	Nuttall oak
Viburnum spp.	Viburnum	*Quercus phellos*	Willow oak
		Quercus pumila	Running oak
		Quercus rubra	Northern red oak

Source: Halls 1977.

has limited its range and reduced population levels. The red-cockaded woodpecker occurs in the open pinewoods, using fairly mature trees with minimal understory (Hamel 1992). Trees also must have proper heartwood conditions for nest cavities. This species has also declined, but active management has stabilized several populations. The sensitive Bachman's sparrow breeds in dense, grassy places where scattered pine trees and saplings are present.

Dodd (1995) reported that 74 amphibians and 96 reptiles occur in the range of the longleaf pine community. These include the flatwoods salamander, Red Hills salamander, striped newt, Carolina gopher frog, eastern indigo snake, gopher tortoise, eastern diamondback rattlesnake, Florida pine snake, and Florida scrub lizard.

Although the influence of longleaf reduction on the herpetofaunal community has not been assessed directly, several species may have been affected. The gopher tortoise, a keystone species in longleaf pine savanna, has declined by 80 percent over the last century (White and others 1998). Amphibians breeding in temporary ponds have been particularly affected by habitat alteration. The flatwoods salamander has disappeared from its eastern range; gopher frogs are nearly extirpated in North Carolina, Alabama, and Mississippi; and dusky salamanders appear to have declined in coastal South Carolina and peninsular Florida.

Conversion of longleaf pine forests to agriculture, slash, or loblolly pine plantations and urban development threaten the continued existence of several herpetofauna species in Georgia and Florida (Ware and others 1993). Hardwood encroachment stemming from fire suppression also has contributed to the loss of longleaf pine communities. Historically, frequent low-intensity fires reduced litter accumulation, controlled competing woody species, and improved herbaceous vigor (Walker 2001). Recent awareness of the importance of this sensitive community has encouraged restoration efforts.

Profiles of selected rare communities: Atlantic white-cedar swamps—Atlantic white-cedar once was distributed from southern Virginia to interior Georgia and from the Florida Panhandle along the Gulf of Mexico to Mississippi. Drainage, development, and harvest without regeneration have reduced Atlantic white-cedar to 10 percent of its original extent.

Much of the original community was destroyed by European settlers who cleared land for agriculture. Today, white-cedar swamps are restricted to inaccessible freshwater wetlands in small, isolated stands. Road construction and the damming of waterways continue to diminish this habitat, as does suburban encroachment, industrial runoff, and pollution.

Atlantic white-cedar swamps are unique communities adapted to variable hydrological regimes, fire, and peat soils. This community type often represents some of the only forest in regions of intense agricultural and urban development. Atlantic white-cedar areas provide habitat for many species, including black bear, deer, rabbits, and other fauna. The diversity of bird species is relatively high in Atlantic white-cedar swamps, compared to adjacent areas. The Hessel's hairstreak is a butterfly that feeds exclusively on Atlantic white-cedar.

During restoration, these stands require frequent, light fires in the dry season. Fire removes competitive vegetation and clears the seedbed for regeneration.

Hard and Soft Mast

Southern species that produce mast—Mast refers to specific kinds of fruits of woody species. Hard mast possesses a hard exterior, as in acorns, while soft mast has fleshy fruits, as in berries. Both forms of mast are important in the diets of southern wildlife. Many southern woody plants produce mast (table 1.11). Mast yields are unpredictable from one year to the next and vary according to species, location, and weather.

Pomes are fruits that have several tough, papery-walled cavities that house seed; the cavities are surrounded by thick flesh. These fruits may be large like apples or small like serviceberries. Fresh pomes have a high moisture and carbohydrate content, but are low in crude protein (Halls 1977).

A drupe is a pulpy fruit with an inner ovary wall that encloses a seed. Drupes are extensively eaten by wildlife. The fruits tend to be low in crude protein and high in carbohydrates; nutrient content varies considerably among species. Drupe producers in the South include wild cherries, plums, hackberry, and red mulberry (Halls 1977).

Berries are fruits with fleshy ovaries that envelop one or more seeds. Most species are eaten by wildlife. Fruits are usually high in carbohydrates and low in crude protein. Species that produce berries include persimmon, blueberry, and grape.

Hard mast includes nuts and one-seeded fruits (or kernels). Most have concentrations of crude fat, and some also are relatively high in crude protein (Halls 1977). Characteristic species include hornbeam, hickory, beech, walnut, black gum, and several species of oaks.

Selected species that utilize mast in their diet—Mast is an essential component in the diets of many vertebrates in the South (Combs and Frederickson 1996, Doherty and others 1996, Jensen 1982, Wolff 1996). Table1.12 lists several mast-consuming mammals, including mice, voles, woodrats, rabbits, raccoons, and foxes. Several birds also consume mast (table 1.13) including game birds (doves, quail, pheasant, grouse, turkey), waterfowl (mallards, wood ducks), woodpeckers, and songbirds (finches, thrushes, jays, and towhees). The relationship between mast and the food habits of several game species, such as deer, bear, and squirrels has been documented extensively (Fridell and Litvaitis 1991, Kirkpatrick 1989, Kurzejeski 1989, Pelton 1989, Wentworth and others 1989).

Selected species that utilize mast in their diet: white-tailed deer—Hard mast is often an important component of the fall and winter diet of white-tailed deer. Nutrition, reproduction, weight, and antler characteristics of individual animals are influenced by acorn availability (Wentworth and others 1989). In poor mast years, reproduction rates may be low, and conception may be delayed. Postnatal survival also can decline following years of minimal acorn production. Fawn weight also can be directly related to the size of the acorn crop.

Table 1.12—Selected mammals of the South that utilize hard and soft mast in their diets

Scientific name	Common name
Castor canadensis	Beaver
Clethrionomys gapperi	Southern red-backed vole
Didelphis virginiana	Virginia opossum
Glaucomys sabrinus	Northern flying squirrel
Glaucomys volans	Southern flying squirrel
Mephitis mephitis	Striped skunk
Neotoma floridana	Eastern woodrat
Neotoma mexicana	Mexican woodrat
Neotoma micropus	Southern plains woodrat
Ochrotomys nuttalli	Golden mouse
Odocoileus virginianus	White-tailed deer
Peromyscus attwateri	Texas mouse
Peromyscus boylii	Brush mouse
Peromyscus floridanus	Florida mouse
Peromyscus gossypinus	Cotton mouse
Peromyscus leucopus	White-footed mouse
Peromyscus maniculatus	Deer mouse
Procyon lotor	Raccoon
Sciurus carolinensis	Gray squirrel
Sciurus niger	Fox squirrel
Spermophilus variegatus	Rock squirrel
Sus scrofa	Wild boar
Sylvilagus palustris	Marsh rabbit
Tamiasciurus hudsonicus	Red squirrel
Tamias striatus	Eastern chipmunk
Urocyon cinereoargenteus	Gray fox
Ursus americanus	Black bear
Vulpes vulpes	Red fox

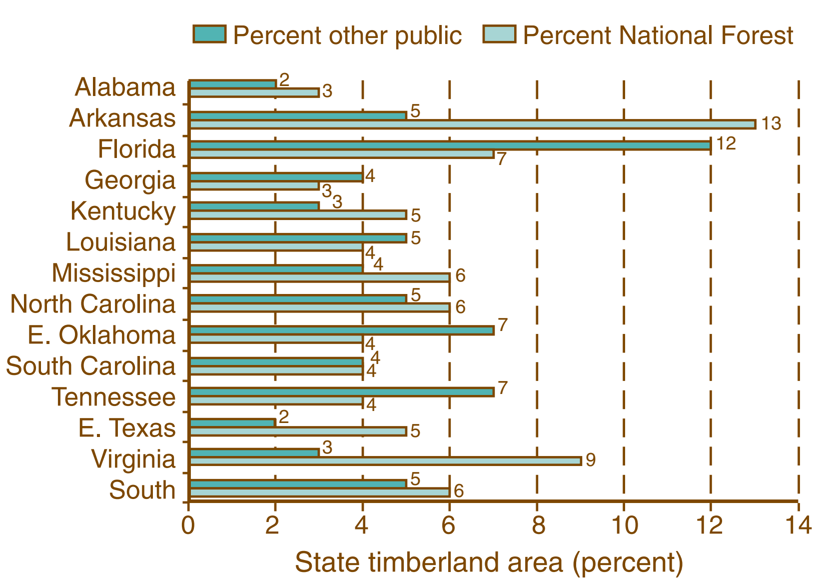


Figure 1.23—National forest and other public ownership of timberland in the South (U.S. Department of Agriculture, Forest Service 2000a).

Selected species that utilize mast in their diet: black bear—The abundance and distribution of oak mast (particularly white oak) also can influence black bear natality, mortality, and dispersal. Shifts in home range sometimes occur in response to fluctuations in hard mast availability. The birth and survival of young bears can be directly associated with oak mast crops (Pelton 1989). Poor mast years often result in increased bear movement, which can result in increased mortality due to vehicular accidents and human-bear interactions. The loss of the American chestnut likely had a significant influence on the population dynamics of black bears in the Southern Appalachians (Pelton 1989). In addition, the reliance on soft mast in the seasonal diet of black bear highlights the importance of early successional habitats in the provision of this food source (Trani and others 2001).

Selected species that utilize mast in their diet: squirrels—The availability of hard mast also can influence squirrel populations. Poor mast crops can result in population declines, while abundant mast crops may result in substantial population increases (Kurzejeski 1989). Mast comprises the majority of the fall, winter, and spring diets of red, gray, and fox squirrels. Acorns, walnuts, and hickory nuts are major food sources for these squirrels as well as for the eastern chipmunk.

Selected species that utilize mast in their diet: game birds—Hard mast provides a high-energy resource for ruffed grouse, wild turkey, bobwhite quail, and several waterfowl. These species consume acorns in proportion to their availability throughout the year; foraging for mast requires little energy expenditure (Kirkpatrick 1989). Red oak acorns have an elevated phenolic content and are less palatable than white oak species.

Factors affecting mast supply availability—In recent years, there have been concerns about the decline of mast-producing species (particularly oaks) in the South. Chapter 16 presents trend information from the FIA on oak and other overstory mast-producing trees. In addition, an examination of oak decline in the South is presented in chapter 18. The factors that may have contributed to the decline, and

Table 1.13—Selected birds of the South that utilize hard and soft mast in their diets

Scientific name	Common name
Aix sponsa	Wood duck
Anas platyrhynchos	Mallard
Anas strepera	Gadwell
Aphelocoma coerulescens	Scrub jay
Bombycilla cedrorum	Cedar waxwing
Carpodacus purpureus	Purple finch
Catharus guttatus	Hermit thrush
Certhia americana	Brown creeper
Colaptes auratus	Northern flicker
Colinus virginianus	Bobwhite quail
Columba fasciata	Band-tailed pigeon
Columba flavirostris	Red-billed pigeon
Corvus brachyrhynchos	American crow
Cyanocitta cristata	Blue jay
Cyanocitta stelleri	Stellar's jay
Ixoreus naevius	Varied thrush
Melanerpes carolinus	Red-bellied woodpecker
Melanerpes erythrocephalus	Red-headed woodpecker
Melanerpes formicivorus	Acorn woodpecker
Meleagris gallopavo	Wild turkey
Mimus polyglottos	Northern mockingbird
Parus bicolor	Tufted titmouse
Parus inornatus	Plain titmouse
Phasianus colchicus	Ring-necked pheasant
Pheucticus ludovicianus	Rose-breasted grosbeak
Philohela minor	American woodcock
Picoides pubescens	Downy woodpecker
Picoides villosus	Hairy woodpecker
Pipilo erythrophthalmus	Rufous-sided towhee
Quiscalus quiscula	Common grackle
Sitta carolinensis	White-breasted nuthatch
Sphyrapicus varius	Yellow-bellied sapsucker
Sturnus vulgaris	Starling
Toxostoma rufum	Brown thrasher
Tympanuchus cupido	Greater prairie chicken
Zenaidia macrocroura	Mourning dove

the subsequent reduction in hard mast production, are briefly mentioned here.

Many variables, including disease, insect infestation, advanced stand age, drought, and disturbance influence oak forests. Mature oaks are quite susceptible to disease and drought conditions. As these forests age, tree vigor is reduced. They become susceptible to windthrow and ice storms. Longevity varies by species and site characteristics. Lack of natural disturbance is another factor. Fire suppression has resulted in an increase in other species in former oak-dominated areas.

Chestnut blight had a dramatic influence on the American chestnut (chapter 18). Chestnut oaks, which replaced chestnuts in many places, are an important source of hard mast for wildlife populations. Gypsy moth infestations on the poor sites occupied by chestnut oaks often inhibit oak regeneration. Infested trees have a reduced capability for stump sprouting, and their acorns lack the energy reserves to remain viable. Repeated defoliation kills many oaks. When this happens, yellow-poplar often captures the site.

Contribution of Public Lands

Extent of public lands in the South—Public land comprises approximately 11 percent of timberland in the South (chapter 16). The distribution of public land between States varies considerably (fig. 1.23). For example, national forests occupy 3 percent of the timberland in Alabama and Georgia but 13 percent of the timberland in Arkansas (U.S. Department of Agriculture, Forest Service 2000a).

FIA data indicate that 4 million acres of timberland are managed by States, 1 million acres by counties and municipalities, and 16 million acres by Federal agencies (U.S. Department of Agriculture, Forest Service 2000a). State land is contained in State parks, wildlife management areas, State forests, and State natural resource areas. Counties and municipalities hold land in local parks and recreation areas, many of which contribute importantly to the conservation of habitat.

The primary Federal land management agencies in the South are the USDA Forest Service, the National Park Service, and the U.S. Fish and Wildlife Service (fig. 1.24). Federal land is concentrated in the Appalachian and Ozark Mountains, with less land in the Piedmont and Coastal Plain. The Forest Service manages approximately 60 percent of the southern Blue Ridge, the eastern edge of the Appalachian Mountain chain. In contrast, less than one-tenth of the mid-Atlantic Coastal Plain is under Federal management.

National parks and the National Park Service—The idea of preserving Federal land in national parks is rooted in the conservation movement of the late 1800s. Created in 1916, the mission of National Park Service was to conserve scenic, natural, and historic resources (Loomis 1993). Congress precluded timber harvesting, mining, and livestock grazing.

In the 1960s, the Leopold Report shifted this preservation philosophy towards ecological management (Loomis 1993). Parks were managed to restore a more natural appearance, and visitor development was directed to areas outside the parks. Park policies allowed fire as a management tool for maintaining the park environment. Recreational activities were limited

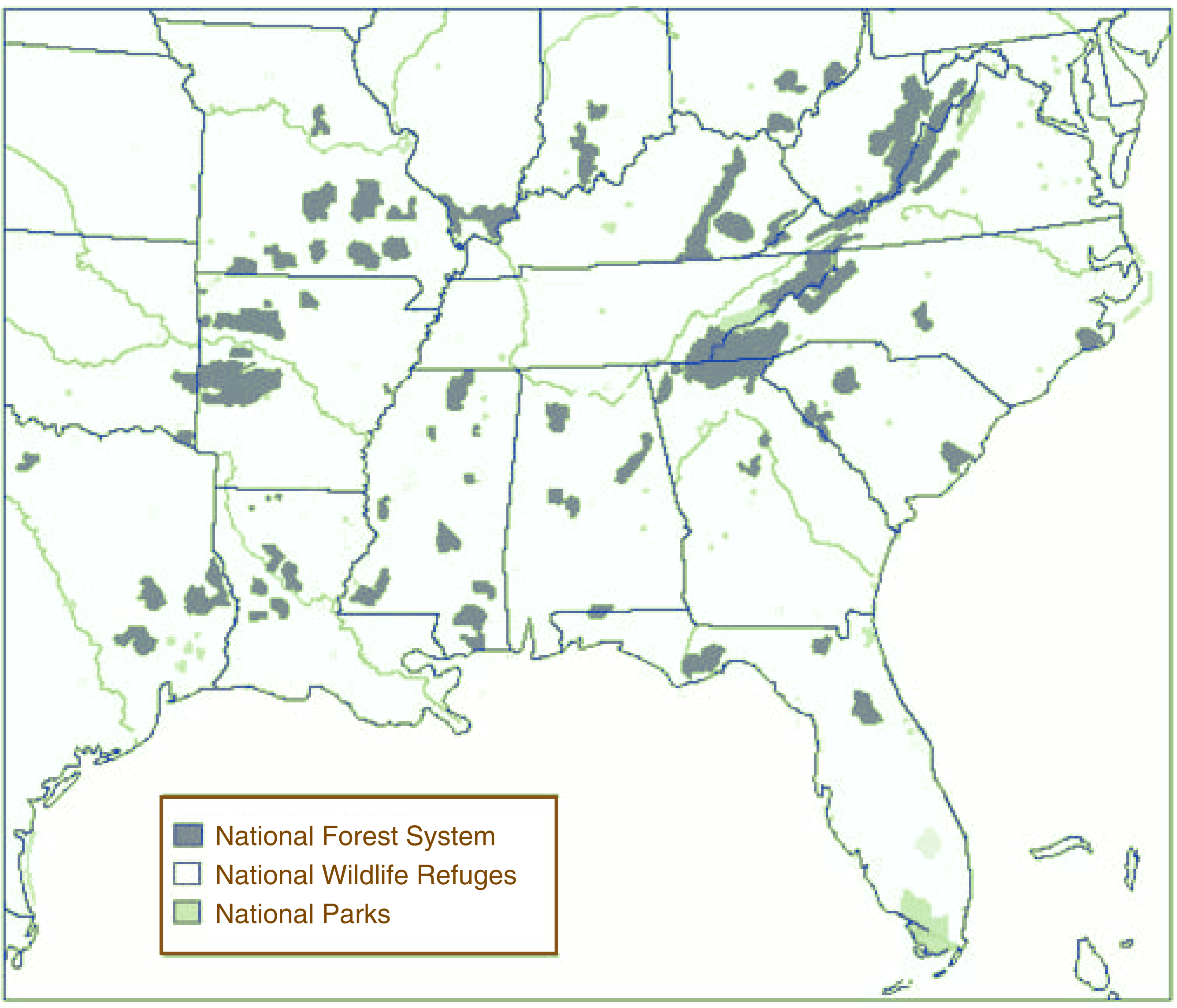


Figure 1.24—The distribution of national forests, national parks, and national willife refuges in the South (White and others 1998).

based upon soil and vegetation characteristics, concerns about water quality, and sensitivity of wildlife to human presence. Still, on National Park Service land there is ongoing conflict between preserving the natural environment and providing for visitor use.

The Agency's current mandate is to perpetuate native plant communities; manipulation of vegetation is kept to a minimum. Species management objectives include the provision of self-regulating populations. Impacts on animal populations are avoided with restrictions on the removal of individual animals.

In 2000, the National Park Service managed 97 properties in the South totaling over 5 million acres (table 1.14). These properties are in seven different designations, each of which is managed with different objectives. National parks contain outstanding natural features and generally are of a sufficient size to ensure protection from outside influences. National preserves also protect selected natural features, but allow uses such as hunting or mining if they do not impair the resources of the preserve. National seashores protect water-related areas of natural significance that occur on the Atlantic and Gulf coasts. National recreation areas emphasize recreational use. Recreational areas also may exist on national forests. National parkways protect scenic resources along travel corridors such as the Blue Ridge Parkway. National monuments and national historic sites (including national battlefields) are established to commemorate historical events (Loomis 1993).

The following area accounts describe selected National Park Service properties that provide valuable habitat for a variety of species in the South. Many areas contain impressive vertebrate diversity or provide examples of applied conservation biology. Property information is summarized from U.S. Department of the Interior, Park Service (2000).

National parks and the National Park Service: Buffalo National River, AR—The Buffalo River is one of the few remaining unpolluted, free-flowing rivers in the South. Stretching 135 miles, the Buffalo River cuts its way

Table 1.14—National Park Service national parks and monuments in the South

National Park Service property	Total acres
Alabama	
National Parks	
Horseshoe Bend National Military Park	2,040
Little River Canyon National Preserve	13,633
Tuskegee Airman National Historic Site (Private)	87
Tuskegee Institute National Historic Site	58
National Monuments	
Russell Cave National Monument	310
Total	16,128
Arkansas	
National Parks	
Arkansas Post National Memorial	749
Buffalo National River	94,328
Fort Smith National Historic Site	75
Hot Springs National Park	5,549
Little Rock Central HS National Historic Site	18
Pea Ridge National Military Park	4,300
Total	105,019
Florida	
National Parks	
Big Cypress National Preserve	720,573
Biscayne National Park	172,924
Canaveral National Seashore	57,662
De Soto National Memorial	27
Dry Tortugas National Park	64,700
Everglades National Park	1,508,607
Gulf Islands National Seashore	135,607
Timucuan Ecological and Historic Preserve	46,000
National Monuments	
Castillo de San Marcos National Monument	21
Fort Caroline National Memorial	138
Fort Matanzas National Monument	228
Total	2,706,487
Georgia	
National Parks	
Andersonville National Historic Site	495
Chattahoochee River National Recreation Area	9,206
Chickamouga and Chattanooga National Military Park	8,119
Cumberland Island National Seashore	36,415
Jimmy Carter National Historic Site	71
Kennesaw Mountain National Battlefield Park	2,884
Martin Luther King, Jr. National Historic Site	34
National Monuments	
Fort Frederica National Monument	241
Fort Pulaski National Monument	5,623
Ocmulgee National Monument	702
Total	63,790

continued

through massive limestone bluffs in the Ozark Mountains. The Buffalo National River has three designated wilderness areas within its boundaries.

Ninety-five thousand acres furnish habitat for 250 species of birds and a variety of animals. It also contains 70 mines that provide important habitat for gray, Indiana, and Ozark big-eared bats. The Buffalo National River also is along the migration route of the federally listed Eskimo curlew.

National parks and the National Park Service: Mammoth Cave National Park, KY—This park was established in 1941 to preserve one of the longest known cave systems (336 miles) in the Nation. The park also was designated as a World Heritage Site in 1981 and an International Biosphere Reserve in 1990.

The park's 52,830 acres support a variety of plants and animals including several bat species of conservation concern: southeastern bat, Rafinesque's big-eared bat, and eastern small-footed bat. There are several State-listed reptiles, including the northern coal skink, glass lizard, and the northern pine snake. Among the 872 flowering species that have been confirmed are 21 listed plants.

National parks and the National Park Service: Congaree Swamp National Monument, SC—This monument was established to protect the largest remaining tract of virgin bottomland hardwood wetlands in the South. The monument is an international biosphere reserve, a national natural landmark, a wilderness area, and a continentally important bird area.

Biodiversity is very high within the Congaree's 22,000 acres. Amphibians that thrive in the deep floodplain sloughs include the marbled salamander, the eastern newt, the southern dusky salamander, and the greater siren. Frogs include the southern leopard frog and the chorus frog. One hundred seventy-three species of birds occur in the monument, including several of conservation concern. Among these are the barred owl, pileated woodpecker, and Swainson's warbler. At different seasons of the year, prothonotary warblers, Mississippi kites, and herons use the refuge. In addition, Congaree Swamp supports important sites for the silver-haired bat, hoary bat, Brazilian free-tailed bat, Rafinesque's big-eared bat, and southeastern bat.

Feral hogs in the park are placing this unique resource at risk. Wetland communities are subject to severe damage from hog rooting and other behavior.

National parks and the National Park Service: Great Smoky Mountains National Park, NC, TN—The Great Smoky Mountains National Park is one of the largest protected areas in the South (521,621 acres) and is World-renowned for the diversity of its plant and animal resources and the integrity of the wilderness within its boundaries. Established as a national park in 1934, it was designated as an International Biosphere Reserve in 1976 and a World Heritage Site in 1983.

The park protects some of the World's finest temperate deciduous forests. Due to the fertile soil and abundant rain, this area boasts 1,650 species of flowers and trees, 50 mammal species, and 27 salamander species. Migrating birds abound in late spring.

Existing and impending threats in the park include invasion by exotic species, air pollution, and forest diseases. Since fire suppression was initiated in the 1930s, oak regeneration has been minimal at some sites with adverse consequences for mast-utilizing species.

National parks and the National Park Service: Big Thicket National Preserve, TX—Big Thicket was the first preserve in the National Park System to protect an area of rich biological diversity. Established in 1974, it also was designated as an International Biosphere Reserve. The preserve consists of nine land units and six water corridors encompassing more than 97,191 acres. The Big Thicket is rich in biological resources and contains swamps, bayous, pine savanna, sandhills, plains, and desert.

National parks and the National Park Service: Shenandoah National Park, VA—This park extends along the Blue Ridge Mountains, encompassing over 198,000 acres. The oak-hickory forest is inhabited by deer, black bear, bobcat, and wild turkey. Species such as the chipmunk, groundhog, raccoon, skunk, opossum, and gray squirrel are frequently detected. Approximately 200 species of birds have been recorded, including flycatchers, thrushes, vireos, 35 species of warblers, and migrating

Table 1.14—National Park Service national parks and monuments in the South (continued)

National Park Service property	Total acres
Kentucky	
National Parks	
Abraham Lincoln Birthplace National Historic Site	337
Cumberland Gap National Historic Park	20,454
Mammoth Cave National Park	52,830
Total	73,621
Louisiana	
National Parks	
Cane River Creole National Historic Park	207
Jean Lafitte National Historic Park and Preserve	20,020
New Orleans Jazz National Historic Park	4
National Monuments	
Poverty Point National Monument	911
Total	21,142
Mississippi	
National Parks	
Brices Cross Roads National Battlefield Site	1
Gulf Islands National Seashore	135,458
Natchez National Historic Park	108
Natchez Trace National Scenic Trail	10,995
Natchez Trace Parkway	51,747
Tupelo National Battlefield	1
Vicksburg National Military Park	1,736
Total	200,046
North Carolina	
National Parks	
Blue Ridge Parkway[a]	88,734
Cape Hatteras National Seashore	30,319
Cape Lookout National Seashore	28,243
Carl Sandburg Home National Historic Site	264
Fort Raleigh National Historic Site	513
Guilford Courthouse National Military Park	220
Moores Creek National Battlefield	88
Wright Brothers National Memorial	428
Total	148,809
Oklahoma	
National Parks	
Chickasaw National Recreation Area	9,889
Oklahoma City National Memorial	6
Washita Battlefield National Historic Site	315
Total	10,210
South Carolina	
National Parks	
Charles Pinckney National Historic Site	28
Cowpens National Battlefield	842
Kings Mountain National Miliary Park	3,945
Ninety Six National Historic Site	989

continued

[a] Property is in two or more States.

Table 1.14—National Park Service national Parks and monuments in the South (continued)

National Park Service property	Total acres
South Carolina (cont.)	
National Monuments	
Congaree Swamp National Monument	21,867
Fort Sumter National Monument	195
Total	27,866
Tennessee	
National Parks	
Andrew Johnson National Historic Site	17
Big South Fork National River and Recreation Area	125,242
Fort Donelson National Battlefield	552
Great Smoky Mountains National Park[a]	521,621
Obed Wild and Scenic River	5,173
Shiloh National Military Park	3,997
Stones River National Battlefield	708
Total	657,310
Texas	
National Parks	
Amistad National Recreation Area	58,500
Big Bend National Park	801,163
Big Thicket National Preserve	97,191
Chamizal National Memorial	55
Fort Davis National Historic Site	474
Guadalupe Mountains National Park	86,416
Lake Meredith National Recreation Area	44,978
Lyndon B. Johnson National Historic Park	1,570
Padre Island National Seashore	130,434
Palo Alto Battlefield National Historic Site	3,357
Rio Grande Wild and Scenic River	9,600
San Antonio Missions National Historic Park	819
National Monuments	
Alibates Flint Quarries National Monument	1,371
Total	1,235,928
Virginia	
National Parks	
Appomattox Court House National Historic Park	1,775
Arlington House, The Robert E. Lee Memorial	28
Colonial National Historic Park	9,349
Fredericksburg National Military Park	7,787
George Washington Memorial Parkway	7,248
Maggie L. Walker National Historic Site	1
Petersburg National Battlefield	2,659
Manassas National Battlefield Park	5,212
Prince William Forest Park	18,661
Richmond National Battlefield Park	1,078
Shenandoah National Park	198,182
Wolf Trap Farm Park for the Performing Arts	130
National Monument	
Booker T. Washington National Monument	224
George Washington Birthplace National Monument	550
Total	252,884
Grand total	5,519,240

[a] Property is in two or more States.
Source: U.S. Department of Interior 2000a.

hawks. Permanent residents include ruffed grouse, barred owl, raven, woodpeckers, and junco. The park also supports several salamander species and two poisonous snakes, the timber rattlesnake and the copperhead snake.

The hemlock woolly adelgid, an exotic insect, currently jeopardizes the eastern hemlocks in the park. First detected 10 years ago, the adelgid is an aphid-like insect that sucks sap from branches of the hemlock. The tree loses strength and sheds its needles, and often does not survive (chapter 17).

National parks and the National Park Service: Blue Ridge Parkway, NC, VA—The Blue Ridge Parkway consists of 469 miles of road and protects the natural features of the Blue Ridge while connecting the Shenandoah National Park with the Great Smoky Mountains. The parkway encompasses 88,734 acres.

The parkway supports several species of rare plants and animals. Some of these, such as the Peaks of Otter salamander and the Blue Ridge goldenrod, do not occur in other southern areas. Ponds and wetlands near the parkway provide essential habitat for amphibians, reptiles, mammals, and birds.

Many Neotropical migrant species return to the parkway each spring. These include the scarlet tanager, veery, wood thrush, and Kentucky warbler. The autumn hawk migration also occurs along the Blue Ridge Parkway. Raptors recorded include the American kestrel, red-tailed hawk, sharp-shinned hawk, broad-winged hawk, golden eagle, and peregrine falcon.

National wildlife refuges and the Fish and Wildlife Service—A network of lands set aside for wildlife began in 1903 with the designation of Pelican Island, FL, as the first National Wildlife Refuge. The Fish and Wildlife Service has responsibility for the Refuge System. Refuge objectives include the provision and enhancement of habitat, perpetuation of migratory bird resources, preservation of natural diversity, and restoration of endangered and threatened species.

Land is acquired for game refuges, waterfowl production areas, and other reasons. Many refuges were created under the authority of the Endangered Species Act, providing anchors for biodiversity and ecosystem-level

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conservation. These areas have been instrumental in the recovery of several species including the whooping crane, Key deer, and American crocodile.

The Migratory Bird Conservation Act of 1929 directed the Agency to purchase areas as refuges for migratory birds. In 1934, the Duck Stamp program established permanent funds for the acquisition of waterfowl habitats. The system has an outstanding record for the successful management of these species. The emphasis on migratory birds has now expanded to include colonial water birds, birds of prey, shorebirds, seabirds, and songbirds.

The earliest form of management consisted of law enforcement and periodic counts of wildlife. As the system expanded, there was an evolution from habitat management for a few species to ecosystem management. For example, planting vegetation for ducks evolved to planting an array of native grasses and forbs to rebuild prairie diversity. Prescribed fire was incorporated to reduce hazardous fuel loads and restore vegetation communities. Management has been altered to mimic natural disturbance for maintenance of a diversity of habitats.

One hundred seventy-two refuges spread across the South encompass approximately 4 million acres (table 1.15). The greatest concentration of wildlife refuges is in Florida and along the Mississippi and Atlantic flyways. Hundreds of species of birds, mammals, reptiles, and amphibians are supported by the diversity of habitats in the Wildlife Refuge System. Several of these properties are discussed in greater detail in the following section. Information on species and communities are summarized from U.S. Department of the Interior, Fish and Wildlife Service (2000).

National wildlife refuges and the Fish and Wildlife Service: Florida Panther National Wildlife Refuge—This refuge supports a variety of habitats, including cypress forests, swamps, pine forests, hardwood hammocks, prairies, marshes, and sloughs. Permanent and seasonal wetlands cover a majority of the refuge area (26,529 acres). The refuge is closed to the public to minimize disturbance to the Florida panther population that occurs there.

Table 1.15—U.S. Fish and Wildlife Service refuges within the South

Refuge	Total acres
Alabama	
Blowing Wind Cave	264
Bon Secur	6,678
Choctaw	4,218
Eufaula	7,953
Fern Cave	199
Grand Bay	2,496
Key Cave	1,060
Watercress Darter	9
Wheeler	34,247
FSA Interest AL[a]	743
Total	57,867
Arkansas	
Bald Knob	14,760
Big Lake	11,036
Cache River	45,232
Felsenthal	64,902
Holla Bend	6,428
Logan Cave	124
Overflow	12,235
Pond Creek	26,816
Wapanocca	5,484
White River	154,856
FSA Interest AR[a]	3,459
Total	345,332
Florida	
Archie Carr	127
Arthur R. Marshall	145,787
Caloosahatchee	40
Cedar Keys	891
Chassahowitzka	30,843
Crocodile Lake	6,688
Crystal River	80
Egmont Key	328
Florida Panther	26,529
Great White Heron	192,584
Hobe Sound	980
Island Bay	20
J.N. Ding Darling	6,315
Key West	208,308
Lake Wales Ridge	1,814
Lake Woodruff	21,559
Lower Suwannee	51,031
Matlacha Pass	393
Merritt Island	139,174
National Key Deer	8,614
Okefenokee	3,678
Passage Key	64
Pelican Island	4,824
Pine Island	602
Pinellas	394
St. Johns	6,256
St. Marks	67,122

Refuge	Total acres
Florida (cont.)	
St. Vincent	12,490
Ten Thousand Islands	35,034
FSA Interest FL[a]	3,124
Total	975,693
Georgia	
Banks Lake	3,559
Blackbeard Island	5,618
Bond Swamp	5,490
Eufaula	3,231
Harris Neck	2,762
Okefenokee	391,402
Piedmont	34,967
Savannah	12,011
Wassaw	10,070
Wolf Island	5,126
FSA Interest GA[a]	4,778
Total	479,014
Kentucky	
Clarks River	5,017
Ohio River Islands	410
Reelfoot	2,040
Total	7,467
Louisiana	
Atchafalaya	15,255
Bayou Cocodrie	13,169
Bayou Sauvage	22,261
Big Branch Marsh	12,642
Black Bayou Lake	1,861
Bogue Chitto	29,493
Breton	9,047
Cameron Prairie	9,621
Catahoula	6,545
D'Arbonne	17,420
Delta	48,799
Grande Cote	6,077
Handy Brake	466
Lacassine	34,379
Lake Ophelia	17,306
Mandalay	4,619
Sabine	140,717
Shell Keys	8
Tensas River	65,746
Upper Quachita	41,063
FSA Interest LA[a]	14,026
Total	510,520
Mississippi	
Bogue Chitto	6,808
Dahomey	9,167
Grand Bay	5,120
Hillside	18,678
Mathews Brake	2,419

continued

Table 1.15—U.S. Fish and Wildlife Service refuges within the South (continued)

Refuge	Total acres
Mississippi (cont.)	
Mississippi Sandhill Crane	19,713
Morgan Brake	7,372
Noxubee	46,914
Panther Swamp	35,272
St. Catherine Creek	24,931
Tallahatchie	4,839
Yazoo	12,940
FSA Interest MS[a]	29,326
Total	223,499
North Carolina	
Alligator River	156,125
Cedar Island	14,482
Currituck	4,317
Great Dismal Swamp	24,812
Mackay Island	7,150
Mattamuskeet	50,180
Pea Island	5,834
Pee Dee	8,439
Pocosin Lakes	108,692
Roanoke River	17,977
Swanquarter	16,411
FSA Interest NC[a]	6,175
Total	420,594
Oklahoma	
Deep Fork	8,387
Little River	12,029
Optima	4,333
Ozark Plateau	2,858
Salt Plains	32,057
Sequoyah	20,800
Tishomingo	16,464
Washita	8,075
Wichita Mountains	59,020
Total	164,023
Puerto Rico	
Cabo Rojo	1,857
Culebra	1,574
Desecheo	360
Laguna Cartagena	1,036
Total	4,827
South Carolina	
ACE Basin	11,772
Cape Romain	65,225
Carolina Sandhills	45,348
Pinckney Island	4,053
Santee	12,483
Savannah	14,839
Tybee	100
Waccamaw	4,978
FSA Interest SC[a]	1,430
Total	160,228
Tennessee	
Chickasaw	22,376
Cross Creeks	8,861
Hathcie	11,556
Lake Isom	1,846
Lower Hatchie	9,353
Reelfoot	8,409
Tennessee	51,359
FSA Interest TN[a]	685
Total	114,445
Texas	
Anahuac	34,296
Aransas	114,397
Attwater Prairie Chicken	9,199
Balcones Canyonlands	16,481
Big Boggy	4,526
Brazoria	43,905
Buffalo Lake	7,664
Grulla	5
Hagerman	11,320
Laguna Atascosa	57,826
Little Sandy	3,802
Lower Rio Grande Valley	77,695
McFaddin	56,181
Moody	3,517
Muleshoe	5,809
San Bernard	30,267
Santa Ana	2,088
Texas Point	8,952
Trinity Point	6,801
FSA Interest TX[a]	1,718
Total	496,449
Virginia	
Back Bay	8,315
Chincoteague	13,598
Eastern Shore	1,570
Featherstone	326
Fisherman Island	1,025
Great Dismal Swamp	83,944
James River	4,195
Mackay Island	874
Martin	146
Mason Neck	2,276
Nansemond	423
Occoquan Bay	642
Plum Tree Island	3,502
Presquile	1,329
Rappahannock River	2,975
Wallops Island	3,373
FSA Interest VA[a]	134
Total	128,647
Virgin Islands	
Buck Island	45
Green Cay	14
Sandy Point	490
Total	549
Grand total	4,089,154

[a] Farm Service Agency.

Source: U.S. Department of the Interior 2000b.

There are several listed species on the refuge. Mammals include the Florida panther and Florida black bear. Avian species include the wood stork, snail kite, bald eagle, and Florida grasshopper sparrow. The American alligator, eastern indigo snake, striped mud turtle, and loggerhead sea turtle are reptiles of conservation concern.

Habitat management objectives center on the provision of optimum conditions for the panther. Other objectives include restoration of natural diversity and implementation of environmental education programs promoting Florida panther and south Florida ecosystems.

National wildlife refuges and the Fish and Wildlife Service: St. Vincent National Wildlife Refuge, FL—This 12,490-acre island refuge is a red wolf propagation site. Additional endangered and threatened species that occur on St. Vincent Island include the bald eagle, piping plover, wood stork, eastern indigo snake, and loggerhead sea turtle.

The primary refuge objective is management and preservation of the natural barrier island and associated native plant and animal communities. Additional management objectives include the provision of habitat for migratory birds and protection of listed species.

National wildlife refuges and the Fish and Wildlife Service: Okefenokee National Wildlife Refuge, GA—Established in 1936, the Okefenokee Refuge covers 391,402 acres. The swamp contains numerous islands and lakes, along with vast areas of nonforested terrain. Prairies cover approximately 60,000 acres of the swamp. Once forested, these marsh expanses were created during periods of severe drought when fires burned vegetation and surface layers of peat.

A wide variety of bird species are supported. The prairies harbor wading birds, including herons, egrets, white ibis, sandhill cranes, wood storks, and bitterns. Scrub-shrub areas support various warblers.

Refuge objectives encompass protection of the unique environmental qualities of the Okefenokee ecosystem, and the provision of optimum habitat for a wide diversity of fish, birds, mammals, reptiles, and amphibians.

National wildlife refuges and the Fish and Wildlife Service: Tensas River National Wildlife Refuge, LA—This refuge lies in the upper basin of the Tensas River in northeastern Louisiana. It includes the site of the last documented sighting of the ivory-billed woodpecker. The refuge supports 65,746 acres of woodlands, croplands, reforested agricultural fields, and open water. The area also is home to the threatened Louisiana black bear.

Management objectives include water management for waterfowl, wading birds, and shorebirds. Cooperative farming provides habitat for migratory birds and bear. Deer are managed via public hunting.

National wildlife refuges and the Fish and Wildlife Service: Alligator River National Wildlife Refuge, NC—This 156,125-acre refuge was established to preserve a unique wetland habitat type, the pocosin, and its associated terrestrial species. Diversity of habitat types includes bogs, freshwater and brackish marshes, hardwood swamps, and Atlantic white-cedar swamps. Plant species include pitcher plants, sun dews, low-bush cranberries, bays, pond pine, red maple, and a wide variety of herbaceous and shrub species common to the South.

Refuge objectives center on the preservation of the unique wetland and the provision of habitat for the red wolf, red-cockaded woodpecker, American alligator, black bear, waterfowl, and migratory birds.

National wildlife refuges and the Fish and Wildlife Service: Mississippi Sandhill Crane National Wildlife Refuge, MS—This refuge occupies 19,713 acres of pine-savanna habitat interspersed with cypress, rivers, and marsh on the Coastal Plain of Mississippi. Water bodies such as Perigal Bayou, Old Fort Bayou, and Bluff Creek flow through various units of the refuge. Approximately 100 endangered sandhill cranes inhabit the refuge.

Refuge objectives center on the provision of habitat for the sandhill cranes and protection of the diverse savanna communities used by cranes. Crane management includes population monitoring, captive bird release, predator control, and law enforcement. Habitat restoration is accomplished via prescribed burning, vegetation manipulation, and noxious weed control.

National wildlife refuges and the Fish and Wildlife Service: White River National Wildlife Refuge, AR—Established in 1935, the White River Refuge contains the largest contiguous block of bottomland hardwood forest under a single ownership in the South.

White River supports one of the largest concentrations of wintering mallard ducks in the Mississippi flyway on its 154,856 acres. Numerous species of wading birds, shorebirds, geese, neotropical migrants, and raptors (including the bald eagle) also inhabit the area.

Refuge objectives center on the provision of optimum habitat for migratory bird and resident species, and support for a diversity of species common to the White River bottoms.

National forests and the Forest Service—The USDA Forest Service was established in 1905 to provide quality water and timber for the Nation. In the subsequent years, the Forest Service embodied the concept of multiple uses. Multiple uses refer to resource management that benefits a variety of purposes while ensuring the productivity and quality of the environment. Benefits include the provision of water, forage, wildlife, wood, and recreation.

The Weeks Act authorized purchase of lands for the National Forest System, especially deforested land, which would be reforested for watershed protection. The Clark-McNary Act (1924) further allowed the Agency to purchase private land that was potentially valuable for timberland production.

Acquisitions under the Weeks and Clark-McNary Acts further added area to the National Forest System.

The mission of the Forest Service centers on four primary objectives: (1) protection and management of natural resources on National Forest System land; (2) research on forests and forest resource utilization; (3) assistance to State and local governments, forest industry, and private landowners for land management; and (4) international assistance for the management of forest resources (Loomis 1993). The Forest Service has recently issued policies for preservation of old growth and maintenance of biological diversity.

National forests are found in 13 Southern States, Puerto Rico, and the Virgin Islands (table 1.16). Over 15 million acres in the South are managed by the Forest Service. National forest ownership ranges from 27,831 acres in Puerto Rico to 2,586,074 acres in Arkansas. In addition to Arkansas, the greatest concentrations of national forest are in Virginia (1,660,428 acres), Mississippi (1,158,967 acres), and Florida (1,152,824 acres). Hundreds of animals and plants are supported by the diversity of habitats in the National Forest System.

National forests and the Forest Service: roadless areas—Roadless areas comprise nearly 1 million acres of the southern national forests (table 1.17). Substantial acreages with this designation are in Virginia (394,000 acres) and North Carolina (172,000 acres). Roadless areas have a range of habitat types and successional seres. Habitat tends to be contiguous, providing refuge from human disturbance that can disrupt species movement and reproduction.

These areas possess ecological characteristics that are rare in developed landscapes, such as large, relatively undisturbed blocks of habitat (U.S. Department of Agriculture, Forest Service 2000b). Invasion of exotic species, erosion, sedimentation, and disruption of water flow are often less likely in roadless than in roaded areas. Species richness may be improved in roadless areas that are large enough to offer a mosaic of habitat patches in various successional stages following disturbance.

National forests and the Forest Service: wilderness areas—Wilderness areas cover 698,513 acres in the South (table 1.18). Arkansas (116,937 acres), Georgia (114,789 acres), and North Carolina (103,226 acres) have the largest amounts of wilderness in the South (U.S. Department of Agriculture, Forest Service 2000c). The Wilderness Act requires that these areas retain their primeval character without permanent developments or human habitation. Roads, timber harvesting, and motorized access are prohibited, but hunting and fishing are permitted.

One objective of managing wilderness is to preserve naturally functioning ecosystems. Relatively large blocks of undisturbed habitat are rare in

Table 1.16—National forest location and acreage in the South

Location	Gross acreage	NFS acreage	Other acreage
Alabama			
Conecuh NF	171,177	83,858	87,319
Talladega NF	740,334	389,328	351,006
Tuskegee NF	15,628	11,252	4,376
William B. Bankhead NF	348,917	180,548	168,369
Talladega PU	11,706	0	11,706
Pea River LUP	40	40	0
State total	1,287,802	665,026	662,776
Arkansas			
Ouachita NF[a]	2,004,231	1,423,459	580,772
Ozark NF	1,496,999	1,136,709	360,290
St. Francis NF	29,729	21,201	8,528
Ouachita PU	1,442	1,442	0
Ozark PU	7,115	3,263	3,852
State total	3,539,516	2,586,074	953,442
Florida			
Apalachicola NF	632,890	565,543	67,347
Chotawhatchee NF	1,152	1,152	0
Ocala NF	430,441	383,573	46,868
Oscala NF	190,932	158,255	32,677
Nekoosa PU	674	223	451
Pinhook PU	171,182	40,025	131,157
Tates Hell-New River	6,863	4,053	2,810
State total	1,434,134	1,152,824	281,310
Georgia			
Chattahoochee NF	1,515,885	749,352	766,533
Oconee NF	260,883	115,231	145,652
Chattahoochee PU	69,302	195	69,107
Ocmulgee PU	10,000	250	9,750
Yonah PU	46	46	0
Forestry Sci. Lab. EA	4	4	0
State total	1,856,120	865,078	991,042
Kentucky			
Daniel Boone NF	1,360,692	547,686	813,006
Jefferson NF[a]	54,614	961	53,653
Land between the Lakes	170,310	170,310	0
Redbird PU	686,399	145,099	541,300
State total	2,272,015	864,056	1,407,959
Louisiana			
Kisatchie NF	1,022,373	603,230	419,143
Bayou Beouf PU	2,264	980	1,284
State total	1,024,637	604,210	420,427
Mississippi			
Bienville NF	382,821	178,542	204,279
De Soto NF	796,072	506,028	290,044
Delta NF	118,150	60,015	58,135
Holly Springs NF	519,943	155,661	364,282
Lyndon B. Johnson NGL	115,438	20,309	95,129

continued

Table 1.16—National forest location and acreage in the South (continued)

Location	Gross acreage	NFS acreage	Other acreage
Mississippi (cont.)			
Homochitto NF	373,497	191,505	181,992
Holly Springs NF	119,155	66,874	52,281
De Soto PU	240	240	0
Homochitto PU	67	67	0
Forest Hydro. Lab. EA	15	15	0
Forestry Sci. Lab. EA (state college)	7	7	0
Forestry Sci. Lab. EA (Gulfport)	10	10	0
Southern Hardwoods Lab EA	3	3	0
State total	2,309,980	1,158,967	1,151,013
North Carolina			
Cherokee NF[a]	327	327	0
Croatan NF	308,234	159,886	148,348
Nantahala NF	1,349,000	527,709	821,291
Pisgah NF	1,076,511	505,420	571,091
Uwharrie NF	219,757	50,189	169,568
Nantahala PU	17,027	737	16,290
Yadkin PU	194,496	0	194,496
Forestry Sci. Lab. EA	27	27	0
State total	3,165,379	1,244,295	1,921,084
Oklahoma			
Ouachita NF[a]	723,552	350,845	372,707
Black Kettle NGL	32,537	30,710	1,827
Rita Blanca NGL	15,816	15,576	240
State total	771,905	397,131	374,774
Puerto Rico			
Caribbean NF	55,665	27,831	27,834
State total	55,665	27,831	27,834
South Carolina			
Francis Marion NF	414,699	252,288	162,411
Sumter NF	960,805	360,868	599,937
Silviculture Watershed Lab EA	15	15	0
State total	1,375,519	613,171	762,348
Tennessee			
Cherokee NF[a]	1,204,520	634,198	570,322
Cherokee PU	7,712	325	7,387
Land between the Lakes	63,852	63,852	0
State total	1,276,084	698,375	577,709
Texas			
Angelina NF	402,231	153,180	249,051
Davy Crockett NF	394,200	160,652	233,548
Sabine NF	442,705	160,656	282,049
Sam Houston NF	491,800	162,996	328,804
Black Kettle NGL	576	576	0
Caddo NGL	68,661	17,873	50,788
Lyndon B. Johnson NGL	115,438	20,309	95,129

continued

Table 1.16—National forest location and acreage in the South (continued)

Location	Gross acreage	NFS acreage	Other acreage
Texas (cont.)			
McClellan Creek NGL	1,449	1,449	0
Rita Blanca NGL	77,413	77,413	0
State total	1,994,473	755,104	1,239,369
Virginia			
George Washington NF[a]	1,635,565	960,133	675,432
Jefferson NF[a]	1,586,343	700,268	886,075
Jefferson PU	1,145	0	1,145
Kimberling Creek PU	271	27	244
State total	3,223,324	1,660,428	1,562,896
Grand total	28,882,907	15,644,482	13,287,425

PU = purchase unit; LUP = land utilization project; EA = experimental area; NGL = national grassland.
[a] Property is in two or more States.
Source: U.S. Department of Agriculture 2000a.

Table 1.17—Summary of inventoried roadless areas in the South

State	Total acreage
Alabama	13,000
Arkansas	95,000
Florida	50,000
Georgia	63,000
Kentucky	3,000
Louisiana	7,000
Mississippi	3,000
North Carolina	172,000
Oklahoma	13,000
South Carolina	8,000
Tennessee	85,000
Texas	4,000
Virginia	394,000
Total	910,000

Source: U.S. Department of Agriculture 2000c.

Table 1.18—Wilderness areas in the South

State	NFS acreage	Other acreage	Total acreage
Alabama	32,167	80	32,247
Arkansas	116,578	359	116,937
Florida	74,495	4	74,499
Georgia	114,537	252	114,789
Kentucky	16,779	658	17,437
Louisiana	8,679	0	8,679
Mississippi	6,046	0	6,046
North Carolina	102,634	592	103,226
Oklahoma	14,543	1,425	15,968
South Carolina	16,671	0	16,671
Tennessee	66,349	40	66,389
Texas	38,483	0	38,483
Virginia	87,064	78	87,142
Total	695,025	3,488	698,513

Source: U.S. Department of Agriculture 2000a.

the South. These are of particular importance to mammals that have large home ranges. Importantly, wilderness contributes to understanding wildlife in an unmanaged setting.

Implications of Habitat Fragmentation on Vertebrate Species

This section reviews the literature on habitat fragmentation and the resulting influence on the species that inhabit those landscapes. Two additional chapters of the Assessment examine fragmentation in the South. Chapter 6 presents an analysis of southern locations using remotely sensed imagery. In addition, chapter 3 examines the influence of roads and power lines on habitat fragmentation.

The definition of fragmentation— The term "fragmentation" is often used to refer to the insularization of habitat on a landscape. The change in arrangement of existing habitats is often accompanied by a loss of habitat area. A landscape may cover hundreds of square miles or a much smaller area. The definition depends on the context of its use and is shaped by the scale at which ecological processes are discussed (Trani 2002).

Fragmentation may occur when a forested landscape is subdivided into patches. Fragmentation may also occur when numerous openings for such things as fields, roads, and power lines interrupt a continuous forest canopy. It also can refer to discontinuities of vegetation in the landscape. Wetland habitat can become fragmented when portions are drained for urban development, while prairie habitat can become fragmented by agricultural development. The resulting landscape pattern alters habitat connectivity and edge characteristics, influencing a variety of species.

Factors that contribute to landscape fragmentation—Landscape fragmentation may result from natural processes such as hurricanes, wildfires, and floods. Landscape fragmentation may also occur in association with land use conversion for urban development, agricultural use, and timber harvesting. The ecological consequences of natural or human-caused fragmentation differ depending on the pattern imposed by these factors.

Landscape modification has occurred for thousands of years. Native inhabitants modified landscapes by burning and clearing forested areas. The first European settlers divided vast forests into farmlands and settlements. This trend continues today. Much of the southern landscape is under intensive management and is becoming an increasingly complex mosaic of forest, urban, and agricultural areas.

Timber harvesting may fragment the landscape, depending on the number, size, and arrangement of harvest units (Trani 1996). Higher levels of fragmentation occur when small, numerous harvest units are dispersed over the landscape than when units are clustered. A dispersed harvest scheme increases spatial heterogeneity, patchiness, and forest edge length. However, the changes in pattern resulting from timber harvest are often temporary because the harvested area regenerates and reverts to forest. The rate of succession depends on the composition of the residual stand, browsing by herbivores, subsequent management activities, weather, and other disturbances (Wigley and Roberts 1994).

It is important to note that a forested landscape supporting a mosaic of different seral stages is not ecologically the same as a landscape containing isolated forested patches surrounded by agricultural or urban areas. Each seral stage provides habitat that varies in suitability for a particular species as it moves through the forested landscape.

Roads may contribute to forest fragmentation when their placement divides large landscapes into smaller patches and interior forest habitat is converted into edge habitat. As road density increases, the populations of some species may become isolated (chapter 3). Roads located along the periphery of a landscape have the least influence on the resulting pattern (Trani 1996). The influence of roads on habitat fragmentation varies with road width and degree of permanence. A six-lane interstate highway has a greater effect on landscape pattern than does a 20-foot forest road. Some roads, such as unimproved dirt roads, may be temporary, while others are paved and permanent.

Influence of landscape fragmentation upon terrestrial species—Harris (1988) cited fragmentation as the most serious threat to biological diversity in the Nation. Area-sensitive species requiring large tracts of habitat may decline or be extirpated locally. The movement of species between patches may be inhibited. Population persistence may be linked to the number, size, and degree of isolation of forest patches (Robbins and others 1989).

Influence of landscape fragmentation upon terrestrial species—The influence of fragmentation on the landscape can be associated with three related factors: (1) patchiness, (2) edge, and (3) connectivity.

Influence of landscape fragmentation upon terrestrial species: patchiness—Changes in patch size have been recognized as a major component of fragmentation. Species richness may decline as patch area is reduced (Ambuel and Temple 1983, Askins and others 1990, Lynch and Whigham 1984). Small remnant patches of forest surrounded by open areas constitute unfavorable habitat for many species; these remnants also have increased susceptibility to windthrow disturbance and other processes. Robinson and Wilcove (1994) suggested that fragmented landscapes become population sinks that are only sustained by immigration from nearby forest tracts that are large enough to produce a surplus of individuals.

Matthiae and Stearns (1981) found that the density of red squirrel, gray squirrel, raccoon, and red fox increased with habitat patch size. Fahrig and Merriam (1985) also reported that certain mammals were more common in large forest tracts than in smaller, isolated patches. Populations of white-footed mice and chipmunks in small forest patches declined to a point that local extirpations occurred.

Rosenberg and Raphael (1986) reported that gray foxes, ringtail cats, and northern flying squirrels were sensitive to forest fragmentation. Picton (1979) found that the presence of large mammals was correlated with the size of the mountain ranges where each species occurs. Mammal population can increase when minimum habitat size requirements are met. The insularity of populations increases with continued landscape fragmentation while larger, undeveloped areas protected these species from extinction.

Roads may or may not act as barriers to the movement of species between habitat patches. Extensive networks of roads have negative impacts on black bears, white-tailed deer, and Florida panthers (chapter 3). These negative impacts stem from loss of habitat, increased hunter accessibility, and vehicular mortality.

Long-term population declines have been observed for neotropical migrants inhabiting small forest patches. Breeding bird censuses for isolated forest patches indicate general reductions in abundance and diversity of species over the past several years (Lynch and Whitcomb 1977). Critical information for the conservation of bird species includes understanding of the relationship between reproductive success and habitat size and quality. The dependence of many breeding songbirds on large blocks of forest is well established (Robbins and others 1989, Whitcomb and others 1981).

Species sensitive to patch size tend to be highly migratory, are forest-interior specialists, build open nests, and/or nest on the ground (Whitcomb and others 1981). The worm-eating warbler, the hooded warbler, and the black-and-white warbler are generally absent in patches less than 50 acres (Hamel 1992). Other species that are sensitive to patch size include the swallow-tailed kite, broad-winged hawk, barred owl, pileated woodpecker, and black-billed cuckoo (Hamel 1992). While many species avoid small patches, widespread permanent residents and short-distance migrants tend to predominate in small patches (Askins and others 1990).

Habitat isolation has been associated with population declines in large snakes due to increasing networks of roads (Gibbons and Buhlmann 2001). These networks divide forested habitat into smaller and smaller parcels. Likewise, amphibian mortality is intensified when a heavily traveled road separates individuals from the forest they live in and the wetland they require for breeding.

Influence of landscape fragmentation upon terrestrial species: edge—An edge is the place where two different plant communities, successional stages, or land uses come together. Fragmentation can increase the amount of edge habitat in a landscape. Inherent edges are caused by changes in soil type or topography, whereas induced edges are those created by disturbance. Induced edges can be created by land uses, including cultivation, fertilization, and harvest, and by environmental disturbances such as fires, blowdowns, and floods.

The creation of forest edge influences seedling establishment and vegetative composition. For some species, these effects persist hundreds of yards into the forest interior (Chen and others 1992). For example, the edge habitat may serve as an access point, attracting cowbirds into the interior of a forested landscape (Askins 1994).

Many species occur in edge habitat, particularly those that use one habitat for food and another for cover. Game birds, such as the American woodcock and northern bobwhite quail, occur in edge habitats. Many species in urban and agricultural landscapes are edge-adapted. Many woodland passerines favor edge habitat (Yahner and Scott 1988), which may provide enhanced forage and/or improved habitat conditions.

In contrast, excessive edge may lead to reduced populations of species dependent on large blocks of forest interior (Robbins and others 1989). Species that use continuous mature forest may be replaced by generalist species. Southern breeding birds that nest only in the interior of forests include the sharp-shinned hawk, Cooper's hawk, hairy woodpecker, winter wren, and veery (Hamel 1992). Edge can negatively affect these species, particularly in patches with large perimeter-to-area ratios (Noss 1983).

An increase in density of forest-edge and farmland species along edges may exclude certain interior and long-distance migrant species. Competition by the edge-adapted starling exerts a direct negative impact on many forest species (Harris 1988). This competition may influence bird community composition more than area-dependent changes in habitat (Ambuel and Temple 1983).

Species that occur in edge habitats are subject to high rates of mortality from predators attracted to these habitats. The raccoon, least weasel, and striped skunk often hunt for small mammals along edges. Ground nests receive predation pressure where mammals and reptiles are the dominant predators (Chasko and Gates 1982). Predation reduces the recruitment of the Kentucky warbler, scarlet tanager, wood thrush, yellow-throated vireo, and ovenbird (Temple and Cary 1988). Increases in edge density contribute to the escalation of nest predation and parasitism to levels that can bring reproductive success below replacement rates.

Nest parasitism by cowbird species may be an important factor in the decline of some breeding birds. Brood parasites lay their eggs in the nests of other species, reducing the reproductive success of their hosts. The brown-headed cowbird may have contributed to the population declines of the Acadian flycatcher, veery, American redstart, and Louisiana waterthrush (Brittingham and Temple 1983).

Influence of landscape fragmentation upon terrestrial species: connectivity—Connectivity, the degree of continuity of a landscape, is also affected by fragmentation. Connectivity may facilitate dispersal and improve habitat quality by connecting patches of habitat. It has been suggested that the population dynamics of species are affected by the spatial pattern of fragmentation (Haddad and others 2000, Hanski 1991). There is disagreement, however, on the value of corridors for the conservation of biological diversity. One view is that populations linked by corridors are vulnerable to the spread of disease and several environmental stressors (Gilpin 1987, Quinn and Hastings 1987). If corridors spread the risk of environmental stress among isolated populations, persistence time may actually be longer in fragmented landscapes (Fahrig and Paloheimo 1988).

Another view suggests that species persistence is lower in fragmented habitats than in contiguous habitats (Tilman and others 1994). These studies suggest that corridors are valuable as a conservation tool. This point of view is discussed next.

Heany and Patterson (1986) presented an extensive review of the regional patterns of mammal distribution as affected by habitat connectivity. Pelton (1986) described how the loss of connectivity restricts the distribution of black bears. When disturbance causes local extirpation, populations may be reestablished through the dispersal of individuals from source populations. Jackson (1987) reported corridors aided red-cockaded woodpeckers in colonizing existing habitat. Forest birds can often use small tracts of forest connected to large tracts by wooded corridors (Robbins 1979). Forest-interior birds and small mammals (Merriam 1990) persist in forest fragments connected by woodland corridors that ease colonization.

Species that are able to move between connected habitat patches operate demographically as a metapopulation. Corridors may permit the survival of extinction-prone populations through the immigration of individuals. Corridors also may facilitate movement of an individual within its home range. Such movement may be particularly important for species whose home range area requirements exceed the average patch size. For example, Rosenburg and others (1997) reported that migratory amphibians, such as red-spotted newts, may require corridors among seasonally used habitats. The loss of connectivity may cause local extirpation. Many amphibian and reptile species cannot move through relatively large, deforested areas to reach other suitable forest habitat. Where declines of herpetofaunal populations occur, population sizes will not be rebuilt quickly in a fragmented landscape (Gibbons and Buhlmann 2001).

Discussion and Conclusions

Status and Trends of Terrestrial Vertebrate Species

Natural Heritage classifies 86 percent of southern vertebrate species as secure or apparently secure. The populations of these species appear to be resilient; some species such as white-tailed deer and beaver have rebounded despite incredible odds. Population trends are positive for several big game, small game, and waterfowl species. In addition, the long-term population projections for several furbearer species appear stable or increasing.

In contrast, declines in the populations of northern bobwhite quail, ruffed grouse, and woodcock warrant further management focus. The decline in breeding populations of grassland and shrubland nesting birds also is a concern in the region. The numerous species with G1, G2, or G3 conservation ranks suggest that these vertebrates are sensitive to changes in their environment. Identifying the factors that contribute to the declines of these species may be useful for predicting future conditions. Several of these factors, as well as their associated conservation measures, are examined in chapter 5.

Significant losses of community biodiversity have occurred throughout the region. Several communities have been classified as critically endangered, endangered, or threatened. An additional 24 communities have been identified as having a 50-percent loss of presettlement area. It is critical to halt further losses of these communities and to raise public awareness through education.

There appears to be a commonality of threats to sensitive species and communities of the South. Many species and communities experienced declines associated with human disturbance and settlement patterns. The growth of human populations in the South will continue to pressure species and the communities that support them. Vertebrate species and their associated habitats are influenced by urban development, fire suppression, agricultural practices, forest pest and exotic species outbreaks, and recreation activity. Other species are rare due to restrictive or specialized habitat conditions (chapter 2).

The future of a majority of these sensitive species and communities in the South depends on active restoration and management. Restoration complements species conservation by maintaining habitat composition, structure, and function. Activities that mimic natural disturbance are particularly important. Prescribed burning can enhance herbaceous diversity and control structural characteristics. Other treatments are useful for suppressing woody growth and enhancing the vigor of other species. These management techniques are described further in chapter 4.

Hard and Soft Mast

For many species, mast is an essential food source. Thus, provision of hard and soft mast is important for the management of terrestrial species inhabiting southern forests.

Many silvicultural techniques enhance mast production (chapter 4). Management of stocking density can encourage reproduction of mast-producing species and limit interspecific competition. Artificial regeneration has been successful for several species, including northern red oak, white oak, and black cherry. Genetic selection for acorn production and seedling growth also has the potential to be successful. These treatments can play an important role in southern forest areas that may experience mast decline.

The Implications of Habitat Fragmentation

Extensive literature suggests that landscape patterns affect the abundance and persistence of terrestrial species. The fragmentation of the landscape, and the consequences of that fragmentation on ecosystems and population dynamics, are concerns shared across the region.

Natural processes and human activities may influence habitat loss and isolation. Changes in patchiness, edge, and connectivity may eliminate, displace, or enhance species populations and habitats. Isolated habitat patches may reduce the number of species present simply because smaller habitats support fewer species (MacArthur and Wilson 1967). Preservation of species composition and integrity in these areas cannot be expected. Corridors may increase the movement of habitat-restricted species, thereby improving overall habitat quality (Haddad and Baum 1999, Rosenburg and others 1998).

Understanding how spatial patterns alter species habitat may provide resource managers with a basis for making land use decisions. Species respond to patterns in various ways, using certain areas for feeding and reproduction, and avoiding other areas entirely. By altering the distribution and availability of spatial resources, changes in landscape pattern influence many of the components important for the persistence of species (Merriam 1990).

The South's growing human population raises the possibility of a substantial impact on species and their habitats in the next several decades (chapter 6). In the midst of expanding populations, the provision of biological diversity has become a critical conservation issue.

The Influence of Land Ownership Patterns

The population increases projected for the South may continually increase demands on natural ecosystems, species, and their habitats during the 21st century (Boyce and Martin 1993). This prospect presents a challenge to forest resource management. Biodiversity often declines as economic development proceeds. Natural habitats for native species are replaced by industrial and urban development, while other habitats are modified or degraded. The future may also bring increased concern for conservation of endangered species and habitats and the reservation of lands for aesthetic and recreation values (Boyce and Martin 1993).

These changes highlight the important role that public lands will have in the conservation of species and their habitats. The Forest Service, Fish and Wildlife Service, and National Park Service manage millions of acres in the South. Other agencies, such as the U.S. Department of Defense and the Tennessee Valley Authority, also manage critical habitat areas. There are numerous Federal policies that dictate the management and conservation of natural resources.

Without these public lands, many species would be in trouble. For example, over 53 percent of the species with viability concerns in the Ozark and Ouachita Highlands are known to occur only on national forests (U.S. Department of Agriculture, Forest Service 1999). The Peaks of Otter salamander is an example of an imperiled species that occurs solely on Federal land—in this case, the George Washington and Jefferson National Forests and the Blue Ridge Parkway. The Federal land in the Florida Panhandle and the central Appalachian Mountains supports concentrations of imperiled and listed species (Stein and others 2000). National wildlife refuges play a key role in the protection of listed species such as the red wolf and the Florida panther, and in the provision of key areas of habitat for waterfowl, migratory birds, and many other species. National parks are important for the preservation and management of old growth, spruce-fir, and other rare and sensitive communities of both plants and animals. National forests are key in the provision of wilderness areas, large blocks of forest interior, and a diversity of habitats.

Other public lands are also important for the conservation of species and their habitats. State agencies own significant areas designated as parks, wildlife management areas, forests, or natural resource areas. While the purposes of such areas vary, the conservation of biological diversity is often one objective for these properties. In Florida, State agencies are carrying out aggressive land acquisition programs for conserving biodiversity, using shared Federal excise tax revenues as a funding source. City and county governments also own a variety of land in parks and recreation areas that support species and their habitats.

Many imperiled and endangered species are found on public land, and this land represents a relatively small percentage of forest land in the South. It seems clear, therefore that public land is vital for maintaining imperiled and endangered species (Stein and others 2000).

The area of public land is being supplemented by acquisition efforts by private conservation organizations. The Nature Conservancy, the Trust for Public Lands, and Ducks Unlimited acquire land for conservation purposes. They either manage it or transfer it to public agencies. The Nature Conservancy has created its own system of conservation properties in the South. In contrast, the Trust for Public Lands acquires land for ultimate ownership and management by public resource agencies. Many of the trust's land transactions have been from forest industry lands that were important biologically.

The magnitude of private ownership also presents a significant challenge for southern forests. Individual landowners are changing the characteristics of future forest resources. For example, the absence of management on private land may result in declines in early successional habitat in many areas (Trani and others 2001). The small tracts typical of present land use patterns often provide little opportunity for forest management and natural disturbance sufficient to create early successional forest. A myriad of species may be influenced by this condition.

The Forest Service and other partners have initiated active reforestation programs with the private sector as part of the Lower Mississippi Valley Joint Venture. Land clearing and alteration of hydrology have resulted in environmental degradation throughout the valley. This step towards changing private land use practices may lead to restoration of the bottomland hardwood system, the provision of quality habitat, economic opportunities for landowners, and a reliable wood supply to meet society's needs.

The significant numbers of imperiled and endangered species inhabiting private land indicate the critical importance of this land for conservation (Stein and others 2000). For this reason, a variety of strategies designed to encourage conservation on private areas have been implemented by government agencies. Incentive programs have been created to encourage reforestation of private land. Recognizing the significance of private land to the imperiled species of the region is essential. Often, wildlife conservation may be more important than timber production on this land.

Industry land also offers opportunities to provide wildlife habitat. Given the incentive of green certification programs and the scale of their operations, many large corporations are taking positive actions to protect sensitive biological resources on their property (Stein and others 2000).

Industry land supports breeding bird species, game species, and other species (Wigley and others 2000). Individual companies work with government agencies to identify threatened and endangered species on their land. The Special Sites program within the Sustainable Forestry Initiative manages ecological sites to maintain wetlands, longleaf pine, and other unique communities (Weyerhaeuser and Price 2001).

Forest industry has also donated thousands of acres to State agencies and the Nature Conservancy (Owen and Helssenbuttel 1989). Donations include the Beryl Anthony Wildlife Management Area in Arkansas (7,000 acres), Great Dismal Swamp National Wildlife Refuge in Virginia (60,000 acres), and several wildlife management areas.

The significance of many types of landowners in the South in providing wildlife habitat cannot be overstated. Each major landowner has an important role to play in the conservation of species and their habitats.

Needs for Additional Research

Data are needed on the distribution, population dynamics, and habitat requirements of many southern species. Basic life history and management information is lacking for several threatened and endangered species. For some nongame birds and game species, standardized inventories lend themselves to regional assessments. For most species, however, there is a dearth of monitoring information from which to evaluate regional conditions.

Centers of amphibian and reptile diversity should be identified in sensitive communities. Long-term monitoring of amphibian and reptile populations is needed to establish population trends. Further study also is warranted to assess the impact the expected climate changes may have on amphibians and other sensitive species.

Further research is desirable into management techniques that mimic natural disturbance for the creation of landscape patterns that are consistent with the evolutionary history of species. Applied research is needed to identify the best approaches, including burning, for restoring degraded communities and maintaining sensitive communities.

Finally, methods should be developed to quantify and forecast influences of human developments on southern biodiversity. We must identify vertebrate species that may be influenced by future habitat fragmentation, and examine how fragmentation attributes change over time.

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Literature Cited

Ambuel, B.; Temple, S.A. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology. 64(5): 1057–1068.

Askins, R.A. 1994. Open corridors in a heavily forested landscape: impact on shrubland and forest-interior birds. Wildlife Society Bulletin. 22: 339–347.

Askins, R.A.; Lynch, J.F.; Greenberg, R. 1990. Population declines in migratory birds in Eastern North America. Current Ornithology. 7: 1–57.

Boyce, S.G.; Martin, W.H. 1993. The future of the terrestrial communities of the Southeastern United States. In: Martin, W.H; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: upland terrestrial communities. New York: John Wiley: 339–366.

Brady, S.J.; Flather, C.H.; Church, K.E. 1998. Range-wide declines of northern bobwhite *(Colinus virginianus)*: land use patterns and population trends. Gibier Faune Sauvage. 15: 413–431.

Brittingham, M.C.; Temple, S.A. 1983. Have cowbirds caused forest songbirds to decline? BioScience. 33: 31–35.

Buckner, E. 1989. Evolution of forest types in the Southeast. In: Waldrop, T.A., ed. Pine-hardwood mixture: a symposium on management and ecology of the type. Gen. Tech. Rep. SE–58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 17–33.

Chasko, G.G.; Gates, J.E. 1982. Avian habitat suitability along a transmission-line corridor in an oak-hickory forest region. Wildlife Monograph. 82: 1–41.

Chen, J.; Franklin, J.F.; Spies, T.A. 1992. Vegetative response to edge environments in old-growth Douglas-fir forests. Ecological Applications. 2: 387–396.

Combs, D.L.; Fredrickson, L.H. 1996. Foods used by male mallards wintering in southeastern Missouri. Journal of Wildlife Management. 60: 603–610.

DeGraaf, R.M.; Miller, R.I. 1996. Conservation of faunal diversity in forested landscapes. London: Chapman and Hall. 633 p.

Delcourt, P.A.; Delcourt, H.R. 1987. Long-term forest dynamics of the temperature zone. New York: Springer-Verlag. 439 p.

Delcourt, P.A.; Delcourt, H.R.; Morse, D.F.; Morse, P.A. 1993. History, evolution, and organization of vegetation and human culture. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 47–79.

Dickson, J.G. 2001. Early history. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 20–30.

Dodd, C.K., Jr. 1995. Reptiles and amphibians in the endangered longleaf pine ecosystem. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 129–131.

Doherty, P.F.; Grubb, T.C.; Bronson, C.L. 1996. Territories and caching-related behavior of red-headed woodpeckers wintering in a beech grove. Wilson Bulletin. 108: 740–747.

Droege, S. 1990. The North American breeding bird survey. In: Sauer, J.R.; Droege, S., eds. Survey design and statistical methods for estimation of avian population trends. Biol. Rep. 90(1). Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service: 1–4.

Echternacht, A.C.; Harris, L.D. 1993. The fauna and wildlife of the Southeastern United States. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 81–116.

Ehrlich, P.R.; Dobkin, D.S.; Wheye, D. 1992. Birds in jeopardy: the imperiled and extinct birds of the United States and Canada, including Hawaii and Puerto Rico. Stanford, CA: Stanford University Press. 259 p.

Fahrig, L.; Merriam, G. 1985. Habitat patch connectivity and population survival. Ecology. 66: 1762–1768.

Fahrig, L.; Paloheimo, J. 1988. Effect of spatial arrangement of habitat patches on local population size. Ecology. 69: 468–475.

Flather, C.H.; Brady, S.J.; Knowles, M.S. 1999. Wildlife resource trends in the United States: a technical document supporting the 2000 U.S. Department of Agriculture, Forest Service, RPA assessment. Gen. Tech. Rep. RMRS–GTR–33. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. [Number of pages unknown].

Fridell, R.A.; Litvaitis, J.A. 1991. Influence of resource distribution and abundance on home-range characteristics of southern flying squirrels. Canadian Journal of Zoology. 69(10): 2589–2593.

Fuller, M.R.; Henny, C.J.; Wood, P.B. 1995. Raptors. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 65–69.

Gibbons, J.W.; Buhlmann, K.A. 2001. Reptiles and amphibians. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 372–390.

Gilpin, M.E. 1987. Spatial structure and population vulnerability. In: Soule, M.E., ed. Viable populations for conservation. Cambridge, UK: Cambridge University Press: 125–139.

Grossman, D.H.; Goodin, K.L.; Reuss, C.L., eds. 1994. Rare plant communities of the conterminous United States. Arlington, VA: The Nature Conservancy. 620 p.

Haddad, N.M.; Baum, K.A. 1999. An experimental test of corridor effects on butterfly densities. Ecological Application. 9: 623–633.

Haddad, N.M.; Rosenburg, D.K.; Noon, B.R. 2000. On experimentation and the study of corridors: response to Brier and Noss. Conservation Biology. 14(5): 1543–1545.

Halls, L.K. 1977. Southern fruit-producing woody plants used by wildlife. Gen. Tech. Rep. SO–16. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 235 p.

Hamel, P.B. 1992. Land manager's guide to the birds of the South. Chapel Hill, NC: The Nature Conservancy. 417 p.

Hanski, I. 1991. Single-species metapopulation dynamics: concepts, models, and observations. Journal of the Linnean Society. 42: 17–38.

Healy, R.G. 1985. Competition for land in the American South: agriculture, human settlement, and the environment. Washington, DC: The Conservation Foundation. 333 p.

Heany, L.; Patterson, B. 1986. Island biogeography of mammals. Journal of the Linnean Society. 28 (1 and 2): 1–271.

Heitmeyer, M.E. 2001. Waterfowl. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 209–223.

Jackson, J. 1987. The red-cockaded woodpecker. Audubon Wildlife Report. 3: 479–493.

Jensen, T.S. 1982. Seed production and outbreaks of non-cyclic rodent populations in deciduous forests. Oecologia. 54: 184–192.

Kirkpatrick, R.L. 1989. Value of acorns for ruffed grouse and wild turkeys. In: McGee, C.E., ed. Southern Appalachian mast management. Unicoi, TN: University of Tennessee, Department of Forestry, Wildlife, and Fisheries: 15–17.

Kurzejeski, E.W. 1989. Squirrel populations and oak mast. In: McGee, C.E., ed. Southern Appalachian mast management. Unicoi, TN: University of Tennessee, Department of Forestry, Wildlife, and Fisheries: 12–14.

Loomis, J.B. 1993. Integrated public lands management: principles and applications to national forests, parks, wildlife refuges, and BLM lands. New York: Columbia University Press. 474 p.

Lorimer, C.G. 2001. Historical and ecological roles of disturbance in Eastern North American forests: 9000 years of change. Wildlife Society Bulletin. 29(2): 425–439.

Lynch, J.F.; Whigham, D.F. 1984. Effects of forest fragmentation on breeding bird communities. Biological Conservation. 28: 287–324.

Lynch, J.F.; Whitcomb, R.F. 1977. Effects of the insularization of the eastern deciduous forest on avifaunal diversity and turnover. In: Classification, inventory, and analysis of fish and wildlife habitat. FWS/OBS 78/76. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service: 461–490.

MacArthur, R.; Wilson, E. 1967. The theory of island biogeography. Princeton, NJ: Princeton University Press. 203 p.

Martin, F.W.; Sauer, J.R. 1993. Population characteristics and trends in the eastern management unit. In: Baskett, T.S.; Sayre, M.W.; Tomlinson, R.E.; Mirarchi, R.E., eds. Ecology and management of mourning dove. Harrisburg, PA: Stackpole Books: 281–304.

Matthiae, P.E.; Stearns, F. 1981. Mammals in forest islands south-eastern Wisconsin. In: Burgess, R.L.; Sharpe, D.M., eds. Forest island dynamics in man-dominated landscapes. New York: Springer-Verlag: 55–66.

Merriam, G. 1990. Ecological processes in the time and space of farmland mosaics. In: Zonneveld, I.S.; Forman, R.T.T., eds. Changing landscapes: an ecological perspective. New York: Springer-Verlag: 121–133.

NatureServe. 2000. An online encyclopedia of life [database]. Version 1.4. Association for Biodiversity Information. http://

www.natureserve.org/. [Date accessed: December].

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience. 33: 700–706.

Noss, R.F.; LaRoe, E.T., III; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biolog. Rep. 28. Washington, DC: National Biological Service. 58 p.

Owen, C.; Helssenbuttel, J. 1989. Wise use of the forest resource. Washington, DC: American Forest Foundation. 40 p.

Pelton, M.R. 1986. Habitat needs of black bears in the East. In: Kulhavy, D.; Conner, R., eds. Wilderness and natural areas in the Eastern United States: a management challenge. Nacogdoches, TX: Stephen F. Austin State University: 49–53.

Pelton, M.R. 1989. The impact of oak mast on black bears in the Southern Appalachians. In: McGee, C.E., ed. Southern Appalachian mast management. Unicoi, TN: University of Tennessee, Department of Forestry, Wildlife, and Fisheries: 7–11.

Picton, H.D. 1979. The application of insular biogeographic theory to the conservation of large mammals in the northern Rocky Mountains. Biological Conservation. 15: 73–79.

Quinn, J.F.; Hastings, A. 1987. Extinction in subdivided habitats. Conservation Biology. 1: 198–208.

Robbins, C.S. 1979. Effect of forest fragmentation on bird populations. In: Management of northcentral and northeastern forests for nongame birds. Gen. Tech. Rep. NC–51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 198–212.

Robbins, C.S.; Dawson, D.K.; Dowell, B.A. 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildlife Monograph. 103: 1–34.

Robinson, S.; Wilcove, D. 1994. Forest fragmentation in the temperate zone and its effects on migratory songbirds. Bird Conservation International. 4: 233–249.

Rosenburg, D.K.; Noon, B.R.; Megahan, J.W.; Meslow, E.C. 1998. Compensatory behavior of *Ensatina eschscholtzii* in biological corridors: a field experiment. Canadian Journal of Zoology. 76: 117–133.

Rosenburg, D.K.; Noon, B.R.; Meslow, E.C. 1997. Biological corridors: forms, function, and efficacy. Bioscience. 47(10): 677–687.

Rosenberg, K.V.; Raphael, M.G. 1986. Effects of forest fragmentation in Douglas-fir forests. In: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Madison, WI: University of Wisconsin Press: 263–272.

Sauer, J.R.; Hines, J.E.; Gough, G.I. [and others]. 1997. The North American breeding bird survey results and analysis. Version 96.3. Laurel, MD: Patuxent Wildlife Research Center. [Number of pages unknown].

Soulé, M.E., ed. 1987. Viable populations for conservation. Cambridge, UK: Cambridge University Press. [Number of pages unknown].

Stein, B.A.; Kutner, L.S.; Adams, J.S., eds. 2000. Precious heritage: the status of biodiversity in the United States. New York: Oxford University Press. 399 p.

Straw, J.A.; Krementz, D.G.; Olinde, M.W.; Sepik, G.F. 1994. American woodcock. In: Tacha, T.C.; Braun, C.E., eds. Migratory shore and upland game bird management in North America. Washington, DC: International Association of Fish and Wildlife Agencies: 97–114.

Temple, S.A.; Cary, J.R. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biology. 2(4): 340–347.

Tilman, D.; May, R.M.; Lehman, C.L.; Nowak, M.A. 1994. Habitat destruction and the extinction debt. Nature. 371: 65–66.

Trani, M.K. 1996. Landscape pattern analysis related to forest wildlife resources. Blacksburg, VA: Virginia Polytechnic Institute and State University. 183 p. Ph.D. dissertation.

Trani, M.K. 2002. The influence of spatial scale on landscape pattern description and wildlife habitat assessment. In: Scott, J.M.; Heglund, P., eds. Predicting species occurrences. [Washington, DC]: Island Press: 141–156.

Trani, M.K.; Brooks, R.T.; Schmidt, T.L. [and others]. 2001. Patterns and trends of early successional forests in the Eastern United States. Wildlife Society Bulletin. 29(2): 413–424.

Truett, J.C.; Lay, D.W. 1984. Land of bears and honey: a natural history of east Texas. Austin, TX: University of Texas Press. 176 p.

U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita Highlands assessment: terrestrial vegetation and wildlife. Rep. 5. Gen. Tech. Rep. SRS–35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 201 p.

U.S. Department of Agriculture, Forest Service. 2000a. Forest inventory and analysis database retrieval system [database]. http://www.srsfia.usfs.msstate.edu/scripts/ew.htm. [Date accessed: July].

U.S. Department of Agriculture, Forest Service. 2000b. Forest Service roadless area conservation. Final environmental impact statement. Washington, DC: [U.S. Department of Agriculture, Forest Service]. [Number of pages unknown].

U.S. Department of Agriculture, Forest Service. 2000c. Land areas of the National Forest System [database]. http://www.fs.fed.us/land/staff/lar/. [Date accessed: July 2001].

U.S. Department of the Interior. 1973. Threatened wildlife of the United States. Washington, DC: U. S. Government Printing Office. 289 p.

U.S. Department of the Interior. 2000a. The national parks: index 1999–2001. Washington, DC: U.S. Government Printing Office. 128 p.

U.S. Department of the Interior. 2000b. Report of lands under control of the U. S. Fish and Wildlife Service. Washington, DC: [U.S. Department of the Interior]. 45 p.

U.S. Department of the Interior, Park Service. 2000. ParkNet: national park guide. http://www.nps.gov/parks.html. [Date accessed: January 2001].

U.S. Department of the Interior, Fish and Wildlife Service. 2000. Southeast region 4. http://southeast.fws.gov. [Date accessed: January 2001].

Walker, J.L. 2001. Sensitive plant communities. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 48–71.

Ware, S.; Frost, C.; Doerr, P.D. 1993. Southern mixed hardwood forest: the former longleaf pine forest. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 447–494.

Wentworth, J.W.; Johnson, A.S.; Hale, P.E. 1989. Influence of acorn abundance on white-tailed deer in the Southern Appalachians. In: McGee, C.E., ed. Southern Appalachian mast management. Unicoi, TN: University Of Tennessee, Department of Forestry, Wildlife, and Fisheries: 2–6.

Weyerhaeuser, R.; Price, W. 2001. Survey of special sites owned and managed by members and licensees of the American Forest and Paper Association. Summary rep. Washington, DC: National Fish and Wildlife Foundation. 43 p.

Whitcomb, R.F.; Robbins, C.S.; Lynch, J.F. [and others]. 1981. Effects of forest fragmentation on avifauna of eastern deciduous forest. In: Burgess, R.L.; Sharpe, D.M., eds. Forest island dynamics in man-dominated landscapes. New York: Springer-Verlag: 125–205.

White, P.S.; Wilds, S.P.; Thunhorst, G.A. 1998. Southeast. In: Mac, M.J.; Opler, P.A.; Puckett, C.E. [and others], eds. Status and trends of the Nation's biological resources. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey: 255–314.

Wigley, T.; Roberts, T. 1994. A review of wildlife changes in southern bottomland hardwoods due to forest management practices. Wetlands. 14(1): 41–48.

Wigley, T.B.; Baughman, W.M.; Dorcas, M.E. [and others]. 2000. Contributions of intensively managed forests to the sustainability of wildlife communities in the South. In: Sustaining southern forests: the science of forest assessment. U.S. Department of Agriculture, Forest Service, Southern Forest Resource Assessment. http://www.srs.fs.fed.us/sustain/conf/abs/wigley.htm. [Date accessed: July 31, 2002].

Williams, M. 1989. Americans and their forests: a historical geography. New York: Cambridge University Press. 599 p.

Wilson, L.A. 1995. The land manager's guide to the amphibians and reptiles of the South. Chapel Hill, NC: The Nature Conservancy. 360 p.

Wolff, J.O. 1996. Coexistence of white-footed mice and deer mice may be mediated by fluctuating environmental conditions. Oecologia. 108: 529–533.

Yahner, R.H.; Scott, D.P. 1988. Effects of forest fragmentation on depredation of artificial nests. Journal of Wildlife Management. 52(1): 158–161.

What are the history, status, and projected future of native plant communities in the South?

Chapter 2: The History of Native Plant Communities in the South

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Key Findings

Nowhere in America is there a greater variety of native plant communities, native plant species, or rare and endemic native plants than in the forests of the Southeast. However, this exceptional bounty of diversity is under increasing stress from habitat conversion, alterations in community composition, and exotic pest and disease species. Human activities have impacted native plant communities since the first aboriginals settled in the region, and humans are likely to remain a formative part of the southern landscape for the foreseeable future.

The human use of native plants and their communities mirror contemporary societal needs. At the beginning of the 21st century the forested plant communities of the South are producing more than ever. Although the vast majority of the region's plant communities have been altered to a greater or lesser extent, an increasingly important societal need is the conservation of natural areas and the restoration of public lands. Rare vascular plant species are not evenly distributed throughout the South. Peaks of rare species diversity occur in the Southern Appalachians, the Florida Panhandle, and the Lake Wales Ridge region of Florida. Secondary peaks of rare species diversity are located in Arkansas' Ouachita Mountains and on the Cumberland Plateau.

Introduction

Native plant communities in the South have been much studied and written about since the Bartrams explored the region in the 18th century (Bartram 1791). Bartram noted that Native Americans as well as European settlers altered native plant communities by intentional burning, land clearing for agriculture, clearcutting of timber, and introductions of exotic species from Europe and the Caribbean. The plant communities of the South were not pristine in Bartram's time, and they were not pristine when Europeans first arrived on these shores. The southern landscape had already seen 10,000 years of human history. The last 400 years, however, have brought more radical changes than any caused by Native Americans.

Today's landscape and vegetation are not only the result of a very long history of change; they are also the starting point of tomorrow's vegetation. To better understand the resource at hand, it is valuable to remind ourselves of how we got here so that, perhaps, we can do better in the future. For the purposes of this Assessment, a native plant community is defined as a set of populations of plants naturally indigenous to an area that are interacting to the extent and degree that would have been observed prior to European settlement and share critical physiognomic and compositional traits.

It is somewhat arbitrary to define what is natural in terms of a pre-European timeframe, because it is impossible to separate the influences of native cultures from the historical landscape. However, even at the height of aboriginal culture in the Southeastern United States, Native Americans could not have had the impact on native vegetation to the degree that the Europeans had.

Plant communities, both native and otherwise, are defined not only by their inter- and intraspecific interactions and composition—which species are present and in what numbers—but also by their structure. Major structural elements include seral stage; the relative abundance, age distribution, and spatial arrangement of dominant species in each canopy layer; as well as physical metrics such as the height, size, and spatial arrangement of individuals. Natural disturbances such as hurricane blowdowns, ice storms, and drought are common events that markedly influence the structural condition of plant communities and have contributed to the perpetuation of a full spectrum of structural and seral conditions.

Methods

The literature was reviewed for information about the history of southern vegetation. There are already several reviews of this material. The better treatments of the subject include Delcourt and Delcourt (1993), Mac and others (1998), Ricketts and others (1999), and Stein and others (2000). An extensive and detailed primary literature exists on the paleobotany of the region based on palynology (the study of ancient pollen). Only a small portion of that information was used in this work, but anyone interested in further reading can consult the reviews of Watts (1980) and Delcourt and Delcourt (1998).

Results

Prehistory of Southern Native Plant Communities

Through providing an understanding of the history of native plant communities in the South, this Assessment hopes to put into context the background against which change has occurred. It is important to understand the roles that global climate change and indigenous human cultures played in shaping the plant communities that are considered native or natural today. In this Assessment, only those works that address the Quaternary, 2 million years before present (BP), and later floras are discussed. The primary focus is on the vegetation history of the Holocene, 10,000 years BP.

For the majority of the Quaternary, the climate of the Southeast has been colder than at present (Greller 1988). During this period, there were multiple continental glaciation episodes that did not affect our region directly, but nonetheless had significant impacts on the composition of our native plant communities. These glaciations have been attributed by most to Milankovitch (1941) variations in the orbit of the Earth about the sun. The components of the Milankovitch cycle are expressed at periods of approximately 100,000, 41,000, and 21,000 years (Delcourt and Delcourt 1993). The effects of each of these cycles have been correlated with the relative severity of glacial periods and the rapidity with which glacial advances or retreats occurred.

The coastlines of the Southeastern United States achieved their present approximate position and shape during the early Quaternary (Christensen 1988). Changes in sea level associated with Quaternary glaciations have profoundly affected the vegetation of the historical Coastal Plains, though due to normal coastal processes, most of the evidence of paleocoastal plant communities has been obliterated. Likewise, the major Quaternary glaciations also profoundly impacted the depositional landscape, especially in the Mississippi Basin.

The composition of native plant communities of the Southeastern United States has changed less than that of any other region in the country during the last 20,000 years (Delcourt and Delcourt 1993). This is not to suggest that plant communities in the South have been static over that period. About 18,000 years ago, at the peak of the last major glacial period, the influence of Arctic air masses and boreal vegetation extended to about 33º N. latitude, the approximate latitude of Birmingham, AL, and Atlanta, GA (Delcourt and Delcourt 1993).

These forests were dominated by various spruce species (*Picea* spp.) and jack pine (*Pinus banksiana*); fir (*Abies* spp.) was abundant in some locations. The understories of these forests were generally typical of modern spruce-fir forests, with the exception of the absence of certain prairie elements (Wright 1981). Today, jack pine is essentially limited to boreal forest types and higher elevations in New England, Wisconsin, Minnesota, and northward. Modern boreal forests dominated by spruce and fir are similarly restricted to New England and Canada.

Temperate deciduous forests dominated the landscape south of 33º N. latitude, to about 30º N. latitude, including most of the then Gulf Coast from about 84º W. longitude. The climate of this region was similar to or slightly drier than modern conditions, based on the analysis of the species present in pollen profiles collected from lake sediments deposited during this time. Oak (*Quercus* spp.), hickory (*Carya* spp.), chestnut (*Castanea dentata*), and southern pine species were abundant. Walnuts (*Juglans* spp.), beech (*Fagus grandifolia*), sweetgum (*Liquidambar styraciflua*), alder (*Alnus* spp.), birch (*Betula* spp.), tulip tree (*Liriodendron tulipifera*), elms (*Ulmus* spp.), hornbeams (*Carpinus* spp. and *Ostrya* spp.), tilias (*Tilia* spp.), and others that are generally common in modern southern deciduous forests were also common then. Pollen of members of the grass, sedge, and sunflower plant families (Poaceae, Cyperaceae, and Asteraceae) were also common in samples from this time period (Delcourt and Delcourt 1993, Greller 1988, Watts 1980).

The vegetation south of 30º N. latitude, in peninsular Florida, was dominated by sand-scrub communities with xeric pine-oak forests in the uplands. Swamps and marshes occupied low-lying and coastal areas (Delcourt and Delcourt 1993, Greller 1988, Watts 1980). The areas that were occupied by coastal marshes at that time are now submerged because sea levels during the time of peak glacial extent were significantly lower than modern levels. The sand-scrub communities still occupy significant areas of upland central Florida (Ricketts and others 1999).

During glacial periods, extensive mesophytic forest communities, similar in character and overall composition to modern lowland and bottomland forests, occurred along major river drainages, especially the Mississippi embayment, the Alabama-Coosa-Tallapoosa Basin, the Apalachicola-Chattahoochee-Flint Basin, and the Savannah River Basin (Delcourt and Delcourt 1993, Greller 1988).

From approximately 15,000 years BP to approximately 10,000 years BP there was a gradual warming trend throughout the region, but the period of 14,000 years BP to about 12,000 years BP was marked by a high degree of climatic variability, including increased seasonality and other climatic extremes (Delcourt and Delcourt 1993). By approximately 10,000 years BP, deciduous forests had expanded northward throughout the region, with pockets of boreal elements remaining only at high elevations in the Appalachian Mountains and in a few other refuges. Broadleaf evergreen and pine forests occupied an area similar in extent to what they occupy today, primarily in the Coastal Plains. Mesophytic and bottomland forest communities continued to occupy the major river drainages of the region (Delcourt and Delcourt 1993).

Although the exact date is in question, this was also the period in which humans first colonized the Southeast. Archeologists date the earliest potential human habitation at approximately 12,500 years BP. Between 12,500 and 10,000 years BP, the human population of the region is thought to have been largely nomadic and very sparsely distributed. Human influence on the region's vegetation was almost certainly trivial and highly localized.

At about this time, many large herbivores that heretofore had been common in the region went extinct (Martin and Klein 1984). Among these animals were the mastodon, ground sloth, and giant bison. In other parts of the World where large grazing animals still exist, they are known to exert a profound influence on the composition and condition of the native plant communities. Likewise, their extinction would lead to a variety of (largely unpredictable) changes. It is not clear why this guild of plant-eating animals disappeared from the region, but overexploitation by aboriginal Americans and an inability to adjust to climatic changes are most often posited. It is certain that their disappearance altered regional patterns of vegetation (Martin and Klein 1984).

At the beginning of the Holocene (10,000 years BP), the climatic conditions in the Southeast were comparable to conditions today (Delcourt and Delcourt 1993). However, the existence of modern climatic conditions does not necessarily imply the existence of modern native plant communities. Although the major modern community types were flourishing in the Southeast by 10,000 years BP, the understory flora had not yet come to resemble modern herbaceous floras. Mixed hardwood forests dominated the majority of the upper Coastal Plains, Piedmont, and lower Mountain regions. Southern pine communities dominated the middle and lower Coastal Plains, whereas evergreens and some remnant boreal elements occupied higher elevation sites. Canopy openings in the mixed hardwood and high-elevation forest regions are thought to have been infrequent and due either to local edaphic conditions or natural disturbance (Delcourt and Delcourt 1993, Watts 1980).

Evidence of human habitation in the region becomes common at about 10,000 years BP (the Paleo-Indian period), but there is little evidence that these cultures had significant or large-scale impacts on the landscape (University of Illinois 1997).

Around 8,700 years BP to approximately 5,000 years BP, a period of significant warming and drying, often called the hypsithermal period, began impacting the vegetation of the Southeast. During the hypsithermal period, extensive expansions of prairies and savannas occurred throughout the region (Delcourt and Delcourt 1993), and xeric oak and oak-hickory forest types proliferated. Many species with more northerly affinities migrated northward and, to the extent possible, upward in elevation. Given the limited heights of the Appalachian Mountains, many of these boreal elements were extirpated during this period. Others were relegated to isolated refuges (Delcourt 1979, Delcourt and Delcourt 1998). Further retraction of boreal forest elements caused a proportional increase in pine-dominated forests in the Appalachians. The hypsithermal was also responsible for the expansion of sand and scrub habitats in central Florida (Delcourt and Delcourt 1993, Watts 1971). The grasslands and savannas of the time expanded and were also linked to the great interior plains grasslands to the west of the region. As a result, elements of the prairie flora became established throughout the region, first by simple migration, but then also by invading disjunct openings (including glades and barrens) that were forming in the canopy of more mesic forests (Delcourt and Delcourt 1993).

During most of the climatic shifts of the last 100,000 years, most plant migration in Eastern North America occurred along a more or less north-south axis. The hypsithermal was significant because it made conditions favorable for the invasion and establishment of species from the center of the continent.

With the warming and drying of the climate throughout the region, species with more mesic proclivities retreated to shrinking riparian and riverine areas.

During this period, the population density of aboriginal peoples increased substantially. The hypsithermal also saw the transition from Paleo-Indian to Archaic Indian cultures. During this period, the Archaic Indians' settlements and populations tended to increase in size. Archaic Indians remained; like their Paleo-Indian ancestors, they were largely nomadic but were able to remain in some areas for extended seasons by practicing more concentrated resource usage. Increased resource use was made possible by technological advances that improved the efficiency of the harvest, collection, and processing of, for example, native plant materials. More concentrated occupation had significant but still local impacts on the abundance and regeneration of tree species (University of Illinois 1997).

At the end of the hypsithermal interval, about 5,000 years BP, all of the components of the modern southern forests were in place. As the climate cooled and precipitation increased, species migrated so that communities were reassembled in new form. The boreal elements of the early Quaternary enjoyed a modest expansion. Riparian, bottomland, and wetland plant communities expanded. Grasslands and savannas contracted and retracted westward.

Within approximately 1,000 years of the end of the hypsithermal, the distribution of species within plant communities of the Southeast had more or less stabilized and would see only minor changes until the colonization by Europeans (Delcourt and Delcourt 1993).

At about 4,000 years BP, the Archaic Indian cultures began practicing agriculture throughout the region. Technology had advanced to the point that pottery was becoming common, and the small-scale felling of trees became feasible. Some of their crop plants, such as corn and squashes (*Zea mays* and *Cucurbita* spp.), were acquired through trading with cultures from the South that had a longer tradition of agriculture (Delcourt 1987). Other crop plants were selected from local natives on the basis of desirable cultivation and harvesting traits. This period also saw increasing emphasis on some forms of passive agriculture, in which existing perennial plants were cared for to increase or improve their output of desired products such as beechnuts or cranberries. Concurrently, the Archaic Indians began using fire in a widespread manner in large portions of the region. Intentional burning of vegetation was taken up to mimic the effects of natural fires that tended to clear forest understories, thereby making travel easier and facilitating the growth of herbs and berry-producing plants that were important for both food and medicines.

Approximately concurrent with the transition from the Archaic Indian culture to the Woodland Indian culture, around 2,800 to 2,500 years BP, aboriginal groups began to establish relatively large settlements. People from these settlements visited sites to exploit specialized resources such as fish, medicinal plants, and cherts. There was a trend, however, toward more permanent occupations to maintain local agricultural plots (University of Illinois 1997). It was during this time that the Mound cultures began to develop and flourish. Woodland Indian Culture evolved into the Mississippian Indian Culture in large portions of the region approximately 1,000 years BP (University of Illinois 1997). Mississippian Culture agriculture became more highly developed, and villages, both large and small, were able to support a more specialized citizenry (Delcourt 1987). Mounds became larger and more numerous, and the amount of land needed to support these populations increased. The majority of Mississippian Culture sites are associated with wetland, riparian, or riverine habitats, and these people became quite expert at altering local hydrological patterns to keep their villages dry and their fields irrigated, and to supply community water needs. In some places, soil erosion became locally significant.

Indian use of fire in land management continued from approximately 4,000 years BP to approximately 500 or 600 years BP (Adams 1992, Cowell 1998, Delcourt and Delcourt 1997). This practice significantly affected the structure of forest stands and the relative abundance of species over large portions of the region. It is not clear to what extent fire influenced the composition or richness of regional floras.

For reasons that are unclear, approximately 500 years ago, aboriginal populations declined significantly throughout Eastern North America and more broadly throughout the Americas. Most anthropologists attribute this depopulation to the transmission and spread of pathogens brought to North America by Europeans. Some communities are known to have lost 98 percent of their population; in general it seems that approximately two-thirds of the Indian population of the Eastern United States was eliminated in a very short time. As a consequence, large areas that had been cleared, burned, and farmed by native peoples were left fallow. Thus, by the time the first European observers were reporting the nature of the vegetation of the region, it is likely to have changed significantly since the regional peak of Indian influence.

A myth has developed that prior to European culture the New World was a pristine wilderness. In fact, the vegetation conditions that the European settlers observed were changing rapidly because of aboriginal depopulation. As a result, canopy closure and forest tree density were increasing throughout the region.

When Europeans started making regular visits to the New World approximately 500 years BP, and during subsequent colonization (specifically in Florida, but also shortly afterwards northward along the Atlantic coast), they also began introducing Eurasian and nonnative tropical plant species. Exotic plants first became prevalent around permanent settlements, especially along the coasts, and then spread inland along travel routes to other suitable locations.

The earliest exotic plants to become established in the region came originally as packing material (often rough hay) in shipping crates or animal bedding material. Later, food, forage, and medicinal plants were introduced in support of the settlements (Carrier 1923). The introduction of exotic animals (especially hogs, cattle, and rats) also began at this time. These animals also have had a significant and permanent impact on the vegetation of the region.

In June of 1527, a group of Spaniards, including Cabeza de Vaca, began a 10-year expedition from Florida along the gulf coast into Texas and on into the American Southwest (Cabeza de Vaca 1542). In his account of the journey, Cabeza de Vaca reported that: (1) the natives of Florida cultivated large quantities of corn; (2) palmetto was abundant and was used commonly for food, fiber, and fuel; and (3) extensive areas of heavy timber (almost certainly longleaf pine) were present with a considerable amount of large woody debris on the ground. The chronicles of other early Spanish explorers, such as Hernando de Soto and Ponce de Leon, contain similarly superficial accounts of the existing native vegetation. The first really useful and widely available information on the natural vegetation of the Southeast was not published until more than 200 years after the Spanish exploration of the region.

Southern Native Plant Communities in Historical Times

Information about the historical native plant communities of the region can be difficult to interpret. Since the modern concept of a plant community did not evolve until the late 19th and early 20th centuries, earlier writers seldom included the kind of information we would like to have for this Assessment. Also, most common paleobotany methods have limited value in the study of historical vegetation, because they have poor resolving capabilities over the relatively short period of the last 500 years. These difficulties aside, there is currently a great deal of interest in the nature of native plant communities at the time of European settlement, largely motivated by the current trend toward restoring such plant communities in the South.

Although Europeans began to explore and settle the Southeast by the mid- and late 16th century, their impact on the native plant communities of the region was limited largely to Coastal Plain, savanna, and bottomland forests. For the most part, the earliest settlements were established in coastal areas and on broad river terraces accessible by boat and barge. Even the rare interior settlements, such as the Arkansas Post established in 1686, were built along major rivers to avail themselves of local patterns of commerce. These areas were often cleared to make way for agriculture. Some of the clearings were made for subsistence farming, but the largest were made for commercial farming and livestock production. The quantity of timber taken during this time was limited both by technology and local demand. Consequently, large areas of upland forest in the South went essentially untouched until the 19th century.

The exploitation of natural resources, such as timber and forage, increased as population increased and as an industrial base was built in North America. Improved agricultural efficiency, a growing population, and better access to European markets by the end of the 18th century provided both the motivation and the capital necessary to expand the conversion of native vegetation to agriculture (Carrier 1923). People began to move westward into the interior of the region and began to clear increasingly large tracts of land. In this era of increased trade, additional exotic species were introduced to the South, and exotic plants that had become well established moved with the expanding population.

Although the Native American population had declined significantly, these people were sufficiently common in the early 18th century to exert a continued impact on wide areas of the southern landscape through their agriculture and, more importantly, their use of fire as a means of manipulating vegetation. The aboriginal practice of burning the forests was adopted by European settlers soon after permanent settlements were established.

Like the Indians, the European settlers of the interior South tended to choose specific areas in which to build homes and farms. Relatively flat topography, access to water and timber, and proximity to trade routes via waterways or overland were important criteria for settlement sites. Such places are most typically found either along the terraces of large river systems or on the Coastal Plain. Consequently, riverine forest communities and longleaf pine communities were the first natural vegetation types in the interior South to be impacted by the expansion of European settlement. However, these native plant communities had long been inhabited by aboriginal people. In some cases, the Europeans removed the Indians by force so that they could occupy their land. Europeans selected and exploited other areas on the basis of their strategic value for military outposts or their proximity to mineral resources. These areas were less common but usually had equally significant impacts on the local vegetation.

Until the 20th century, the economy of the South was based largely on agriculture. Technology changed the kinds of crops grown, especially for the export market. From the late 18th century until the early 20th century, resin extraction from pines, especially longleaf pine, for use by American and European navies shaped the management of longleaf pine forests in the Coastal Plains. The naval stores industry, based on the processed and unprocessed resin, or tar, used to seal the hulls of ships and many other things, began to decline with the development of metal hull ships at the end of the 19th century. Large farms became common in the region by the early 19th century, due in great part to technological improvements like the invention of the cotton gin in 1793. Until the beginning of the 19th century, tobacco accounted for the majority of southern exports; thereafter and well into the 20th century, mechanized cotton production dominated the South. Large tracts of agricultural land were created out of the native plant communities of the Coastal Plain where cultivation was relatively easy. This form of land use also greatly affected longleaf pine communities, as well as a wide range of hardwood communities that existed on river terraces.

Increases in farm size had the effect of concentrating economic power in the hands of relatively few established families and companies. There was little incentive for these families to develop new centers of agriculture or diversify the crops being grown. The majority of new settlements in the interior South were based either on a subsistence economy or service to relatively small areas. Certain areas were completely converted to agriculture, with permanent and deleterious implications for the native plant communities. In areas dominated by subsistence farming, less obvious impacts to the native plant communities occurred, such as the disruption of population processes caused by fragmentation, the introduction of exotic species, impacts on rare communities such as mountain bogs and glades, and widespread alterations in forest community structure related to timber harvesting and fuel-wood gathering.

There was considerable curiosity in 17th and 18th century Europe about North American ornamental and medicinal plants. In fact, most of the "botanists" of this time were collectors for wealthy Europeans. These botanists, however, usually did not catalog the natural resources of the region. It was left to the early 18th century botanists from the Northeast to first explore and describe the vegetation of the Southeast. Most notable among these early explorers were John (1699-1777) and William Bartram (1739-1823).

The Bartrams made several journeys of botanical exploration and collection and published accounts of the natural history of the areas that they visited. William Bartram's "Travels through North and South Carolina, Georgia, East and West Florida . . ." became an international bestseller shortly after being published in 1791. This success was no doubt due in part to John Bartram's reputation and to his and William's extensive correspondence with European botanists. William Bartram states that the purpose of his trip through the South was the "discovery of rare and useful products of nature, chiefly in the vegetable kingdom," and to "obtain specimens and seeds of some curious trees and shrubs (which were the principal objects of this excursion)."

Although "Travels through North and South Carolina, Georgia, East and West Florida . . ." is full of details of soil conditions in various places, lists of species encountered, and in some cases detailed descriptions of particular species, Bartram did not generally offer useful accounts of the native plant communities. He did record the occurrence of many of the broad community types we are familiar with, including forests, savannas, glades, and swamps, described in such terms as ". . . expansive green meadows or savannas, in which are to be seen glittering ponds of water, surrounded at a great distance, by high open pine forests and hommocks, and islets of oaks and bays projecting into the savannas . . . ."

He also noted large areas of clearcut longleaf pine (Bartram 1791, p. 312) and "expansive ancient Indian fields" (Bartram 1791, p. 458). Bartram was particularly interested in the agricultural potential of the South, noting not only the areas used by the aboriginals for cropping (e.g., Bartram 1791, p. 511), but also areas that would be suitable for the cultivation of European crops as diverse as olives and oranges (Bartram 1791, p. 337). He also documents the early trade in useful native plants such as ginseng (Bartram 1791, p. 327) and rosinweed (*Silphium*) (Bartram 1791, p. 398). Bartram also offers accounts of introduced species such as barnyard grass (*Echinochloa*) (Bartram 1791, p. 430) as well as a description of Franklin tree (*Franklinia altamaha*) (Bartram 1791, p. 467), a species that is now extinct in the wild. Perhaps most remarkable about the landscapes described by Bartram is that many of these places remained unchanged until the late 19th century.

Thomas Nuttall, traveling in the Arkansas Territory around 1819 (Nuttall 1821), also described what he saw in general terms: thickets of dwarf oaks, hills of pine and oak, and scattered areas of prairie. He too noted the effect of the human hand on the landscape, mentioning annual fires set by the white settlers and extensive areas of cutover pine. Nuttall cataloged many nonwoody plants as well. As was customary at the time, he did not elaborate about the specific conditions in which these plants were growing, but simply stated this or that species was growing under oaks, along streams, or high upon a hill.

Bartram and Nuttall are the most important of the early botanical explorers of the South, but their work is of limited value in determining the nature of native plant communities in existence at the time. Their approach reflected the contemporary philosophy of natural history and botany. At the beginning of the 19th century, ecology was not yet a word, much less a science. Linneaus had developed his natural classification system only a half century earlier; there was not yet a concept of natural selection or evolution, and it was a time of global exploration and discovery. All of the major seafaring European nations were establishing colonies around the World. The purpose of this exploration was the acquisition of power and wealth, and because many plants were the source of great wealth, botanists were needed to travel to "unexplored" parts of the World to catalog the plant life. At the time, this was called phytogeography, a term that describes the endeavor well enough. The primary concern of phytogeographers was to identify the location and distribution of plant species. While phytogeography was a necessary step in the development of plant ecology, at the beginning of the 19th century little effort was expended on describing the interrelations among the species that were being so faithfully cataloged.

After Bartram and Nuttall, a procession of botanists and naturalists, often physicians with an interest in botany, collected plants in the areas around their homes. For the most part, these collectors did not directly contribute to the understanding of the distribution of native plant communities. However, their work would become important later, in the late 19th and early 20th centuries, as regional floras for the South were developed.

In 1835, the first railroad system in the South began operating in North Carolina, in the heart of the longleaf pine forests of the Coastal Plain (Croker 1987). The industrial revolution had brought to the South the means by which its abundant forest resources could be transported great distances and still turn a tidy profit. The longleaf pine forests of the Coastal Plains were not only a source of high-quality timber for a growing population, but also the Nation's most important source of naval stores. The naval stores industry began in North Carolina and spread throughout the Coastal Plains with the railroad (Croker 1987). By 1854, the railways had reached the Mississippi River.

In the mid-19th century, clearcutting was the primary logging method employed. Modern forestry, as practiced in Europe at the time, would not become commonplace in North America until the early 20th century. In the first half of the 19th century, extensive areas of forest were leveled to create pastureland. In many places the native forest has never recovered. Forested areas surrounding major river ports were extensively cut to fuel steamboats. Vast acreages of wetlands and river terraces were drained or plowed by the mid-19th century, causing significant losses to local biodiversity in some areas. Strip mining, especially for coal to stoke hungry steamboats and railroad locomotives, became commonplace where deposits were sufficiently shallow to exploit, such as the Upper Cumberland Plateau. Strip mining eliminated forest cover and frequently altered or killed riparian and aquatic plant and animal communities downstream from the spoil piles. Although much of this activity in the region slowed during the 1860s, logging resurged quickly thereafter. By the 1880s, a broad sector of Americans, mostly in the Northeast and West, were becoming concerned about the unbridled exploitation of the Nation's forest and wetland resources.

The evolution of forest protection laws and the establishment of national forests in the South parallel the development of the modern conservation movement in the United States (Williams 2000). Issues such as farmland erosion, forest clearcutting, and the hyperexploitation of buffalo were on the national conscience. The first use of the word conservation in the context of the protection of natural resources was in 1875, by John Warder, president of the American Forestry Association. The leadership of America's conservation movement was borne by Gifford Pinchot, John Muir, Charles Sargent, and Theodore Roosevelt.

The Federal Government began setting aside tracts of land as forest reserves when Congress passed the Forest Reserve Act of 1891 (Williams 2000). This legislation allowed the President to "from time to time, set apart and reserve, in any state or territory having public land bearing forests, in any part of the public lands, wholly or in part covered with timber or undergrowth, whether commercially valuable or not, as public reservations . . . ." Federal forest administration was consolidated under the leadership of Gifford Pinchot in 1905 with the establishment of the U.S. Department of Agriculture's Forest Service (Williams 2000). The first national forest established in the South was the Arkansas National Forest (1907). Two national forests in Florida were added to the growing system in 1908 (Ocala and Choctawhatchee). Most of the national forests throughout the South are a result of the Weeks Act of 1911. This act broadened the mandate of the Forest Service and provided for the purchase of land, largely for watershed protection. From the time of their establishment until the beginning of the Second World War, the national forests of the South served primarily as conservation areas (Williams 2000). National forest lands have since been critical refuges of functional native plant communities in the South.

At the turn of the 20th century, the logging industry in the South was producing lumber at its historical peak. So much forest land had been logged out that timber companies were finding it difficult to access merchantable trees and were beginning to close mills and move to the newly opened virgin timberlands of the Northwest. Although the First World War caused a short-lived resurgence in the demand for timber and naval stores, the conversion of the shipbuilding industry to steel by 1920 caused demand for southern timber and naval stores to fall drastically. By 1930 the majority of the Coastal Plains longleaf pine communities had been essentially cut over (Croker 1987), as had the interior shortleaf pines (*P. echinatus*). Upland hardwood forests fared somewhat better, at least in some places.

After 300 years of land conversion and alien plant introduction, it is no surprise that in the early part of the 20th century exotic plant species were common throughout the region. Some had been planted purposefully as ornamentals, as forage for livestock, or increasingly as erosion control agents by State and Federal agencies. Others were simply accidental tourists that made their way across the region without the direct assistance of people, in stocks of hay or the coats of domestic animals. Palmer (1926) notes an abundance of "introduced species [and] adventive woody species" in the vicinity of Hot Springs, AR. He specifically noted Japanese honeysuckle (*Lonicera japonica*), Princess tree (*Paulownia tomentosa*), and many other introduced species.

Vascular plants were not the only exotic species introduced to the United States during historical times. Among the most destructive exotics were fungal pathogens of trees. Chestnut blight (*Cryphonectria parasitica*) was introduced into this country in New York in 1904. It spread rapidly and was actively killing trees in the Southern Appalachians by the 1920s. By the early 1950s, American chestnut (*Castanea dentata*) was ecologically extinct throughout its range in Eastern America. This species once was a dominant tree of Appalachian forests. In some areas, one tree in four was a chestnut. Although loss of the chestnut was significant in terms of change in forest composition, there is some disagreement about the ecological impact of chestnut blight. Only one species extinction is suspected to have resulted from the blight (American chestnut moth, *Ectodemia castaneae*); and the greatest impacts to native plant communities seem to have been a change in tree density (a temporary result of canopy gaps created by the death of chestnuts) and a realignment of dominant overstory tree species resulting from competition (Stein and others 2000, Woods and Shanks 1959). Different trees have replaced the chestnut as the dominant canopy species in different portions of the chestnut's former range.

Dutch elm disease (*Ophiostoma ulmi* and *O. nova-ulmi*) entered the United States in 1930 in logs imported from Europe. There is differential susceptibility among *Ulmus* species, but the American elm, a common street and landscaping tree, has been the hardest hit. By the late 1970s Dutch elm disease was known to have impacted elm trees throughout the country (Schlarbaum 1997).

Butternut canker (*Sirococcus calvigigenti-juglanacearum*), which impacts *Juglans cineria*, was first observed in the United States in 1967, but it is believed to have been infecting trees for many years by that time. By 1995, the USDA Forest Service estimated that over three-quarters of all butternut trees had perished from the disease (Schlarbaum 1997).

There have been many other exotic disease-causing fungi and insects that have had significant impacts on the native plant communities of the South. Examples include white pine blister rust (*Cronartium ribicola*), the gypsy moth (*Lymantria dispar*), and the balsam wooly adelgid (*Adelges piceae*). Many introduced disease organisms are still impacting our native plant communities, and it is likely that new pests will be periodically introduced to our region. No one can tell what damage they might bring in the future. For a more thorough discussion of the impact of exotic diseases of forest trees, see chapter 17 of this report.

The study of the flora of the South was in some respects dependent on the publication of local and regional floras. Improvements in the knowledge of the botany of the region required these tools. Several local floras had been published for portions of the South, including Walter's Flora Caroliniana (1788), Mohr's Flora of Alabama (1901), and Gattinger's Flora of Tennessee (1901). The first comprehensive flora of the Southeast was published in 1860 by Chapman. It was an important though incomplete work. Unfortunately, it seemed to stifle further serious assessments of the local flora of the region until the early 20th century. It was not until 1903, with the publication of Small's Manual of the Southern Flora, that the region had a comprehensive, systematic flora. Revised in 1933, Small's Manual is a monumental work of 1,500 pages and was the standard of southern botany floras for over 50 years (Reveal and Pringle 1993). The last 20 years have seen the development of several important new floras [e.g., Smith (1994) and Wunderlin and Hansen (2000)].

The lack of specific information about native plant communities in the South from settlement times to the end of the 19th century is the product of two conspiring circumstances. First and foremost, the Southeast has been continuously occupied for longer than any other region of the United States: by the early 19th century, when the Nation became interested in its natural resources, the focus was on the wild and unknown West rather than the familiar South.

Secondly, the development of plant ecology as a modern science took place largely in Europe beginning in the early and mid-19th century. There and then the concepts of succession and plant associations were first developed into forms recognizable today. However, at the time, the study of plant ecology was a subdiscipline of plant geography. Plant geography, the description of the distribution of plants, was the primary concern of European academics, capitalists, and naturalists. In the 19th century, naturalists from many nations were traveling around North America cataloging plants. The pinnacle of plant geography studies was reached in the early 20th century and coincided with the rise of the modern study of plant ecology. The earliest focus of the fledgling field of ecology was the study of plant community succession. That research was done in the midwestern plains and eastern forests.

Henry Cowles first described the dynamic (changing) nature of vegetation. Prior to Cowles, plant geographers were content to map the current condition and extent of vegetation. Many of Cowles' students went on to make important contributions to the study of succession throughout North America. E. Lucy Braun became renowned for her descriptions of virgin forests in the Eastern States, especially the

Appalachian Mountains. Her work is still read and used as a reference.

Fredrick Clements was arguably the first community ecologist in America. Working largely with prairie and old-field communities in the Midwest, Clements described much of the vegetation of North America, named many plant associations, and identified successional stages for his named communities. He described the plant community as a form of superorganism to indicate his perception of the interdependence of all of the parts of a community, and he described succession as the development or life cycle of the organism.

Clements notion of the superorganism was not universally accepted. In 1926, Henry Gleason, who conducted his research in forested communities similar to those common throughout the South, wrote an influential paper that criticized Clements views and posited that the nature of plant associations is determined by the individualistic behavior of plant species. Gleason's individualistic notion of plant communities eventually won out over Clements idea of the superorganism.

The complexity of southern forest plant communities hampered the development of a comprehensive and consistent community classification system, such as those developed early in the history of land management in the Midwest and West.

Beginning with the study of plant succession in the first quarter of the 20th century, a practical science of plant and community ecology evolved. From this point forward meaningful data became available about the nature of native plant communities. However, because the South had been settled for centuries, by the early 20th century, vast tracts of native plant communities had been converted, planted, logged over, infested with weeds, or otherwise impacted, so opportunities to study intact native communities were rare.

The Great Depression of the early 1930s was exceptionally difficult for the people of the South, but it did a lot for the native plant communities of the region. The Federal Government purchased land and established many national forests. The Civilian Conservation Corps (CCC), established in 1933 during the Franklin Roosevelt administration, did extensive reforestation in the South. The formal teaching of forest sciences in the United States had finally matured by the 1920s and 1930s, so that an abundance of well-trained foresters working for the USDA Forest Service, State forestry agencies, and the CCC itself were available to supervise and direct the work (Williams 2000). The fledgling USDA Forest Service was working to control unauthorized timber cutting on Federal land. Unfortunately, this was also the time in which widespread fire suppression activities began. Although this practice was well intentioned at the time, it eventually led to significant declines in native plant communities throughout most of the Southeast.

The timber industry in the South remained depressed until the outbreak of the Second World War. At about the same time, serious scientific research was started at government and university labs to increase the productivity of forest land. Much of this work focused on the development of "improved" tree selections and cultivation practices. One of the innovations that arose was the growing of pines in plantations.

Plantation cultivation of pines turned out to be exceptionally productive. Newly developed tree selections thrived in the prepared conditions of the plantation. Large tracts of cutover land, especially in the Coastal Plain and Piedmont, would eventually be converted to pine plantations. This method focused timber production on developed sites. Although those sites were forever altered, this intensive form of silviculture saved many acres of native forest from more traditional timber harvesting.

The next large threat to native plant communities in the South came from another, unlikely advancement in technology. From the time of settlement the South was largely rural, agrarian, and sparsely populated. The widespread availability of air conditioning in the 1950s and 1960s made living and conducting business much easier in the sweltering heat of southern summers. The South, therefore, began to see significant increases in immigration and urbanization. Land was developed, and large tracts were fragmented. These trends led to rapid increases in demand for building materials, electricity, and additional agricultural production.

Improvements in technology and mechanization (especially in agriculture) and decreasing Federal commodity price supports led to significant consolidations in the timber and farm industries. Former farmers migrated to cities in the North and South. In the 1940s, 42 percent of the population in the South lived on farms. By the 1950s, only 15 percent of southerners lived on farms. The majority of the population of the region became isolated from the landscape, forever changing the way southerners viewed their forests.

After the end of the Second World War, pine forests in the South, including those on State and Federal land, were predominantly managed for timber production. The birth of the modern conservation movement in the 1960s came, in part, as a reaction to concerns about public land management priorities and the lax enforcement of environmental laws.

The Current Condition of Native Plant Communities in the South

Ecosystems—In the Southeastern United States, interacting aggregations of plant and animal communities and the abiotic factors affecting them are as diverse as any in the World. No place in North America has more diverse forests in terms of plants or animals, or more different types of forests. One very important source of this diversity in plant communities in the Southeast is the exceptionally high degree of endemism (occurrence restricted to a particular region or area) in the regional flora, especially in Coastal Plain conifer forests and in Appalachian forests.

In contrast, the South has the greatest absolute number of introduced plant species in North America. Florida alone reports 800 introduced species existing outside of cultivation (FLEPPC 2001).

One of the most important tools in the study of any system, including plant communities, is a comprehensive means of classifying the observed diversity. Several large-scale vegetation classification methods are in current use; the most important are those described by Kuchler (1985), Bailey (1994, 1998), and The Nature Conservancy (TNC) (1999). Each of these systems divides the region on the basis of either general physiography or potential natural vegetation. Although many other methods exist, these methods illustrate the basic philosophies of large-scale vegetation classification. Although most vegetation classification systems are in agreement on the general distribution of regional plant communities, there is still much discussion and continuing research concerning how to define the transitions between vegetative communities.

Small-scale community classification can be generally useful in understanding the dynamics of local vegetation. Hierarchical and geographically comprehensive systems such as TNC's National Vegetation Classification System (Anderson and others 1998, Grossman and others 1998) define literally thousands of plant associations based on the presence of dominant and associated species. The utility of this system (and similar systems) is its inherent flexibility.

One of the most useful qualities of TNC's National Vegetation Classification System is the assignment of rarity ranks to plant communities (Association for Biodiversity Information 2001). A comprehensive system of rarity ranks across the Nation allows for an assessment of the geography of community diversity.

According to TNC figures, the Southeastern United States has the highest number of endangered ecosystems of any region of the country. More than 30 percent of all natural plant communities throughout the Southeast are critically endangered, and the Southeast has the highest proportion of imperiled plant communities in the United States, exclusive of Hawaii (Stein and others 2000). A great number of the rare plant communities in the Southeast are inherently rare, and their rarity is a function of the great plant diversity in the region. However, the majority of rare communities in the Southeast are rare because of habitat alteration or degradation.

The majority of inherently rare plant communities are relatively small patches of plants in unique combinations, often due to the presence of equally rare edaphic conditions. These patch communities can be seen as occurring within a matrix of more common, widespread community types. Most habitat conservation activities tend to focus on the patch habitats.

Because there has not been a single consistent convention for the identification of plant communities during the majority of the history of the Southeast, it is essentially impossible to discuss the specific changes to those plant communities over time. However, this is not to say that we cannot assess the overall trends in conditions of plant communities. On the basis of conversion, alteration, and impedance of function, more than 99 percent of all plant communities in the South are not in the condition they were in prior to European settlement. Some of these changes have been subtle, but most are readily distinguishable. It is impossible from the perspective of current times to know precisely what has been lost, but we can estimate the general loss sustained by southern native plant communities.

Among the communities to have seen the greatest change in historical times are the region's forests. All of the forests of the South have been touched, directly or indirectly, at one time or another, by the hand of humanity. Sometimes that hand has been gentle, but in most cases it has not.

By some estimates, all of the upland hardwood forests of the Appalachians have been altered. The hardwood forests have suffered from chestnut blight, Dutch elm disease, and butternut canker. Even if the impact of disease is discounted, less than 10 percent of the original native forest area of the region has not been eliminated or altered. Most was cleared prior to the 1930s. Estimates vary from State to State, but, on average, approximately half of all presettlement hardwood forest has been eliminated (Walker and Oswald 1999), and the majority (essentially all) of what remains is compromised by fragmentation, exotic pest and disease organisms, and altered natural processes such as fire and livestock grazing (Mac and others 1998, Noss and others 1995).

Coastal Plains longleaf pine forests, renowned for their high levels of diversity, endemism, and species rarity, have been reduced by more than 98 percent, compared to presettlement conditions. Most have been converted to agriculture or pine plantations, two plant communities notable for their lack of diversity, endemism, and species rarity. Most of the longleaf pine forests were cut by the 1920s, but longleaf pine habitat was still being clearcut and converted into plantations in the 1980s (Noss and others 1995, Stein and others 2000). They were used as a source of timber since aboriginal times, but European settlers were clearcutting vast areas of longleaf pine by mid-18th century. Longleaf that was not cut for lumber was commonly used as a source of naval stores beginning in the 17th century, a practice that continued into the early 20th century (Croker 1987). The remaining large blocks of longleaf exist almost exclusively in public forests (notable privately owned large tracts of longleaf include the Moody tract in southern Georgia and Green Swamp in North Carolina). Many areas of longleaf forests are being managed for the endangered red-cockaded woodpecker. Remaining blocks are, in some places, threatened by exotic plant species, such as Cogon grass (*Imperata cylindrical*), fire suppression, and some forestry (site preparation) practices that disturb the forest understory plants, in lieu of burning, to facilitate the growth of the trees. There is also much concern, but little that can actually be done, about the fragmentation of the original longleaf community (Croker 1987). Only minor fragmentation agents, such as roads, can be managed to increase longleaf habitat continuity, whereas the major fragmentation factors—conversion to agricultural and urban land uses—are essentially intractable. Many public land management agencies are currently practicing longleaf forest restoration activities, and others are encouraging restoration on private land. These efforts, while very important, vary greatly in their success. While it is relatively simple to successfully grow longleaf pine, the reconstitution of the original plant community is very difficult.

Fewer than 50 percent of the presettlement spruce-fir forests still exist in the Appalachians (Noss and others 1995). Of that quantity, more than 98 percent either have been altered or are under attack by introduced pests. Over 90 percent of the red spruce forests in central Appalachian forests have been lost (Noss and others 1995).

Approximately 90 percent of the forested habitats in Florida have been altered or eliminated, including 60 to 75 percent of the forested uplands of Lake Wales Ridge, an area of exceptionally high species rarity and endemism. Only on the Atlantic and Gulf coastal barrier islands does a majority of the natural forest cover remain. It has survived due to its isolation and unsuitability for agriculture or development (Noss and others 1995, Stein and others 2000).

More than 98 percent of the presettlement old-growth forests in the South have been altered or lost (Stein and others 2000). The vast majority of the remaining old-growth forests in the South are on Federal land in national forests and national parks. Of the original 60 to 90 million acres of Coastal Plain pinelands, only 3 percent survive today as old growth (Croker 1987, Noss and others 1995, Walker and Oswald 1999). Less than 2 percent of the forests in Kentucky have old-growth characteristics (Noss and others 1995). In Tennessee, only about 5 percent of the presettlement old-growth forest on the Cumberland Plateau remains, and no more than 20 percent of the forest of Tennessee's Blue Ridge Province can be classified as old growth (Noss and others 1995). Those few tracts of old growth not on public land are mostly in fragments of 100 acres or less, which reduces their value (Stein and others 2000). Most of the forest types classified as old growth today are actually second- or third-growth forests that have or are developing the structural characteristics of old growth.

Open habitats in the South such as glades, barrens, and prairies were common at the time of European settlement, as noted by the earliest travelers to the region. There are, however, no good estimates of how much of the landscape was occupied by these open areas. The current best approximation suggests that as much as 10 percent of the plant communities of the South were historically open habitats (Mac and others 1998). Today, approximately 1 percent of the forested landscape of the South is occupied by openings such as barrens, prairies, and glades. In most cases these areas are very small, and they are not integrated across the landscape (Mac and others 1998, Stein and others 2000) as they once were.

Among open habitat types, prairies seem to have suffered the greatest losses. Settlers saw these relatively flat, treeless, and fertile areas as productive and easy to clear. In Kentucky, less than 200 acres of an original 3 million acres of native prairie remain (Noss and others 1995). In Texas, Louisiana, Florida, Mississippi, and Arkansas, nearly 99 percent of acres originally in prairie types have been lost (Noss and others 1995).

The majority of glades that survive today tend to occur in mountainous regions that were never converted to agriculture, and they typically have very stony soil. There is no information on the total area in glades throughout the region, but estimates are that less than half of the original glade habitat in the region survives intact, and the majority of that which remains is ecologically compromised due to either the presence of exotic species or the lack of fire. In Tennessee, approximately one-half of all the area in cedar glades has been converted (Noss and others 1995). Limestone glades throughout the region have been disturbed at higher rates (Noss and others 1995), probably because they are more commonly located at lower elevations and in areas of gentler topography.

High-elevation grassy balds are mountaintop treeless areas. Although the mountains on which these open areas occur are not high enough to have alpine plant communities, various edaphic and historical circumstances have conspired to keep these areas treeless. Grassy balds tend to support herb-rich communities that require frequent disturbance (Greller 1988). Their ecological origin is still a matter of debate. About 50 percent of the area that was occupied by grassy balds in 1900 remains today (Mac and others 1998).

Almost all of the wet hardwood forests, such as those that occur in bottomlands and hammocks on the tropical Coastal Plain, have declined to approximately 20 percent of their presettlement cover (Mac and others 1998, Noss and others 1995). A slightly larger percentage of the original floodplain forests has survived (Noss and others 1995), but most of it was cleared at some time in the past and has returned to forested cover in the last century. In the last 25 years, accelerated efforts have been made to restore floodplain forest, especially in the Mississippi Valley.

The Southeast comprises only 16 percent of the land area of the lower 48 United States, but it contains 36 percent of all wetlands and 65 percent of forested wetlands. About 78 percent of all wetlands in the Southeast has been altered to some degree (Noss and others 1995).

Unique or isolated wetlands have fared worst overall. Although the Southeastern United States has the highest diversity of carnivorous plants in the World, the habitat in which these plants occur has declined by approximately 97 percent. Reed wetlands, known as canebrakes, have been reduced by more than 98 percent (Mac and others 1998). Mountain bogs, especially those in the Southern Appalachians and Blue Ridge, are home to a great variety of unique native plant species. Although approximately 10 percent of these bogs remain, few are in fully functioning ecological condition (Mac and others 1998).

Pocosins, upland wetlands that occur on the Coastal Plain, have been reduced to about 20 percent of their original area (Mac and others 1998, Noss and others 1995). Similarly, only about 10 percent of the original Atlantic white-cedar forests, which require frequent, low-intensity fires and are typically only seasonally wet, are left (Noss and others 1995).

Table 2.1—Percentage of wetland acres lost in Southeast, 1780s through 1980s

State	Loss
	Percent
Alabama	50
Arkansas	72
Florida	46
Georgia	23
Kentucky	81
Louisiana	46
Mississippi	59
North Carolina	49
Oklahoma	67
South Carolina	27
Tennessee	59
Texas	52
Virginia	42

In the early 1600s, there were approximately 220 million acres of wetlands in the lower 48 States (Mitch and Gosselink 1993). Nationwide, over one-half of wetland acres have been converted to other uses. The degree of wetland loss has been less on the Coastal Plains, thanks in part to restoration and conservation activities that began in the 20th century. Today, only 28 percent of Coastal Plain wetlands have been permanently converted (Noss and others 1995), but a significantly higher proportion have been impacted by human management and exotic plant species.

The degree of loss of wetlands varies widely among States within the South (table 2.1) and is complicated by the large-scale alterations of wetlands and hydrology conducted by humans. Countless acres of wetland have been drained either for agriculture, pasture, or urbanization, and countless other acres were lost during stream channelization, diking, or deforestation (Mac and others 1998, Mitch and Gosselink 1993, Noss and others 1995). The rate of wetland conversion was greatest (Mitch and Gosselink 1993) from the 1950s through the mid-1970s. Since the 1970s the States with the greatest rate of wetland loss nationwide are all in the South: Arkansas, Florida, Mississippi, North Carolina, and South Carolina (Mitch and Gosselink 1993).

The condition of the native plant communities discussed in this chapter is reflective of the condition of the majority of native plant communities in the South. In fact, it is exceptionally rare to find pristine plant communities. Even the most remote places have been affected by invasive exotic plants, introduced disease organisms, changes in community structure and function stemming from altered fire and hydrological regimes, and even changes in the local seed- and pollen-dispersing animals.

Rare Plant Species in the Southern Region

Plant communities, whether rare or common, comprise species that share similar ecological needs and tolerances. The diversity of plant species in the South is rivaled in North America only by the California flora. This diversity is due in part to a broad array of species that are either highly localized in their distribution or are very sparsely distributed over large areas.

Two widely accepted classes/categories of plant species endangerment are protected under the Endangered Species Act of 1973 (ESA); and TNC has commonly used the category of "imperiled species" (Association for Biodiversity Information 2001).

Within the Assessment area, approximately 115 plant species are listed as either threatened or endangered under the ESA (U.S. Department of the Interior, Fish and Wildlife Service 2001). Of this number, 52 occur in Florida. Those species are clustered in the Appalachicola and Lake Wales Ridge areas. The Southern Appalachians contain the next greatest concentration of threatened and endangered plant species.

Figures 2.1 and 2.2 show the distribution of rare plant taxa in the South by equal-area hexagons and counties, respectively. These maps were derived from data held by State Heritage programs and represent the occurrences of vascular plant species with a TNC rarity rank of G1-G2. These are species considered to be critically imperiled or imperiled (Stein and others 2000) based on the number, size, and condition of populations known to exist. The distribution of rare taxa is used here as a proxy for the distribution of plant diversity. Low-diversity plant communities such as agricultural lands or beaches rarely contain uncommon taxa, whereas there is a Worldwide pattern of uncommon species being associated with highly diverse plant communities. The occurrence data represented in figures 2.1 and 2.2 should not be interpreted as the distribution of plant species on a trajectory toward extinction. Most of the rare plants in the South (or the World for that matter) are species that are naturally rare (Rabinowitz 1981). These data are, in all likelihood, incomplete in that private lands may be under-surveyed for rare plants, and some States have generally better surveys than others. However, figures 2.1 and 2.2 represent the best available data at this time and are more than adequate to elucidate the overall pattern of species diversity and rarity in the South.

These figures display three hotspots of plant diversity in the South: the Southern Appalachian Mountains, the Appalachicola lowlands of the Florida

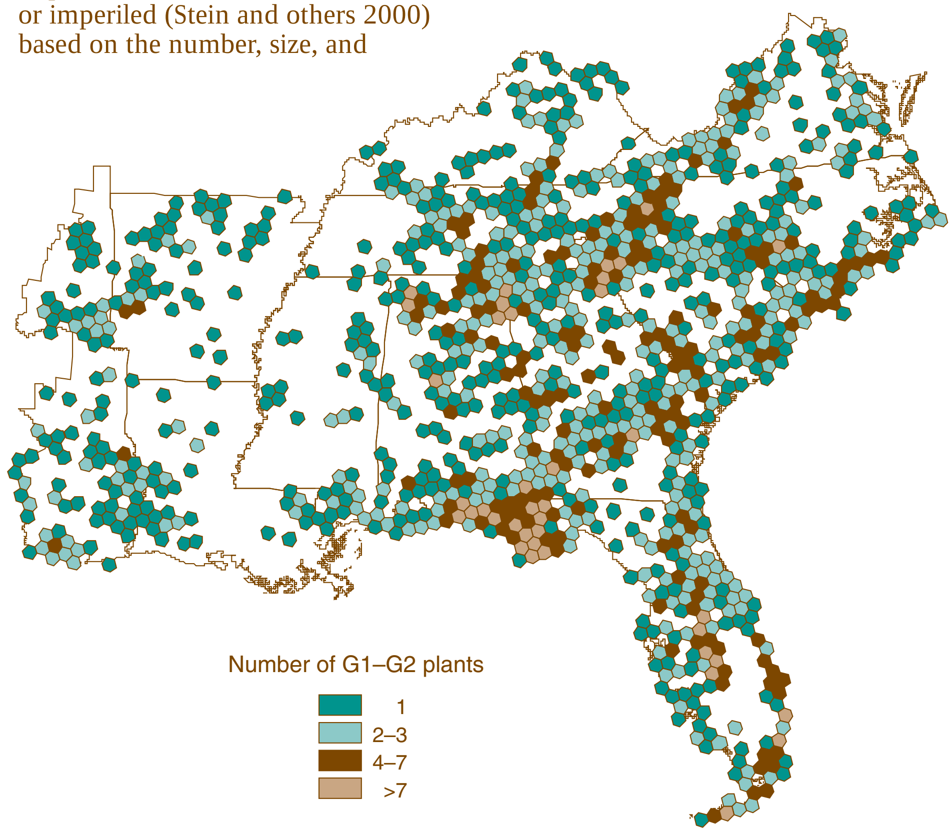

Figure 2.1—Distribution of imperiled vascular plant species in the South based on the number of occurrences in equal-area hexagons.

Panhandle, and the Lake Wales Ridge region of central Florida. The Southern Appalachians are a refuge for a wide range of species in genera with generally more northerly affinities. Many of the rare taxa in the Southern Appalachians are thought to be relicts from periods of glaciation in the distant past. The Lake Wales Ridge hotspot is a portion of Florida that was submerged during times of rising sea levels, such as during the hypsithermal period from 8,700 to 5,000 BP. Many of the rare plants on Lake Wales Ridge are thought to have been more widely distributed in the past. The Apalachicola lowlands plant diversity hotspot is more difficult to explain. Although the area has a striking diversity of habitats such as karst features, a variety of bogs, and wiregrass communities, these factors alone are unlikely to be the cause of the richest endemic flora in the South. Some scientists have suggested that some combination of habitat diversity, generally markedly low levels of soil nutrients, and a long history of frequent fires has made the area a challenge for most plant species and an opportunity for the evolution of specialized taxa.

Other areas with important levels of plant diversity in the South include the Coastal Plain, the Ozark-Ouachita Highlands, and the Cumberland Plateau.

Although most of the rare plant species in the South are species that are naturally rare, forest fragmentation and land conversion have significantly impacted the distribution and abundance of a large number of species. Other factors associated with human density, such as over-harvesting and hydrologic alterations, have diminished many species that were formerly common.

Many of the plant diversity hotspots represented in figures 2.1 and 2.2 occur primarily or largely on public land. This result highlights the importance of public land for the conservation of rare plants. Although not all public land management practices favor rare plants, in many places public land is the only place in which rare plant conservation is politically or economically possible.

Discussion and Conclusions

Plant communities of the South deserve many superlatives. They are exceptionally diverse, being rich in both the number of species and the number of endemic taxa. Forests of the South are also among the most heavily impacted in North America. They are severely fragmented, have experienced greater levels of human habitation for longer than any other forests in North America, and have the greatest number of exotic species. The native plant communities of the South have a history of increasingly intensive use, but recent changes in social attitudes are a source of great hope to those who appreciate the very special qualities of the native southern landscape. There is no chance that the South will ever see the communities that Cabeza de Vaca and De Soto saw, or even the relatively more modified landscapes first described by Bartram and Nuttall. In fact, continuing urbanization and population pressures will almost certainly conspire to keep the majority of the South's landscape working hard to support its people (table 2.2). However, the remaining public land in the region is increasingly being managed for uses other than commodity production, and native plant community restoration and species protection activities on both public and private land are at an all-time high. Changes will continue into the future, most of them detrimental to the overall health of native plant communities in the South. Increasing human populations and resource demands will further fragment the remaining forests and natural areas. Invasive species will occupy increasingly larger proportions of the southern landscape. Global climate change will also impact the composition and distribution of plant communities in the South. However, increasing awareness of the value of forests and natural areas has slowed the pace of land conversion in the South, and recent efforts by State and Federal Government landowners to improve forest conditions through restoration suggest that, at least in part, some of the inevitable changes coming to southern native plant communities will be improvements. The native plant communities of the South will never be what they were, but if the future brings increasing functionality to the remaining intact ecosystems of the

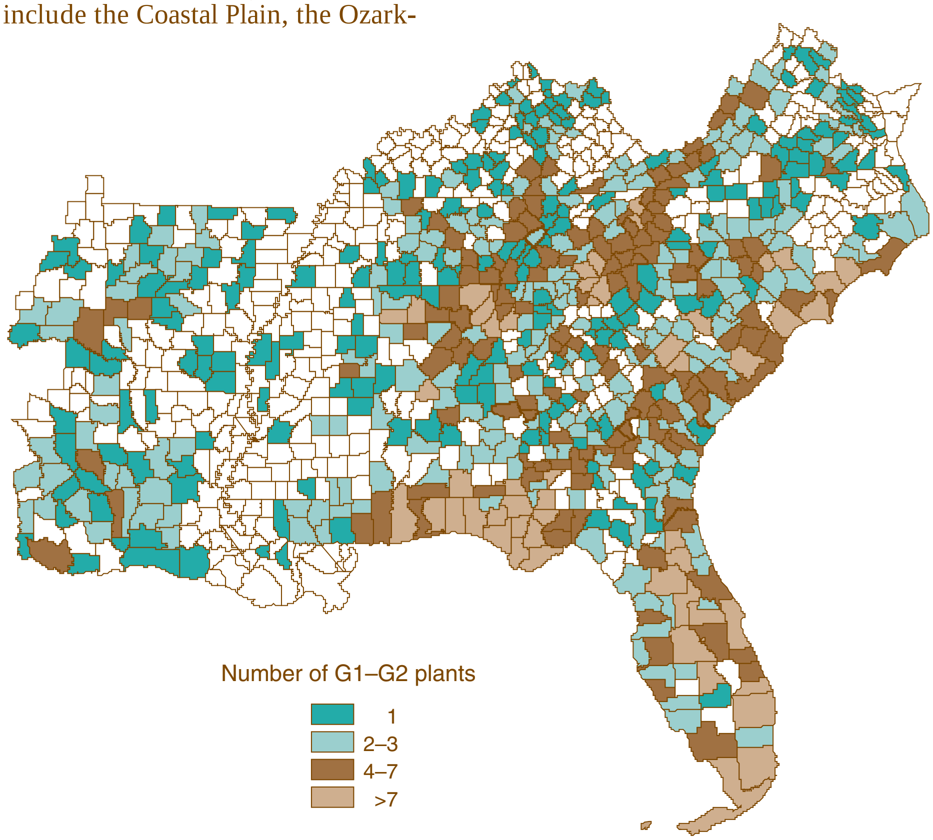

Figure 2.2—Distribution of imperiled vascular plant species in the South based on the number of occurrences in counties.

Table 2.2—Timberland in Southern States by ownership class

State	Hardwoods All ownerships	Hardwoods National forests	Hardwoods Industrial forests	Softwoods All ownerships	Softwoods National forests	Softwoods Industrial forests
	Acres (thousands)					
Alabama	21,931.9	605.4	5,499.4	7,447.1	237.2	2,789.9
Arkansas	18,392.1	2,371.8	4,514.6	5,077.0	831.8	2,450.3
Florida	14,650.7	1,029.5	4,601.5	7,437.8	725.5	2,921.9
Georgia	23,796.1	710.7	4,890.5	10,805.4	192.4	3,154.3
Kentucky	12,347.3	698.9	204.5	682.1	64.2	0
Louisiana	13,783.0	568.5	4,422.5	5,006.7	327.9	2,357.1
Mississippi	18,587.4	1,106.6	3,314.1	5,751.0	505.3	1,579.7
North Carolina	18,710.4	1,082.4	2,420.4	6,261.9	168.0	1,528.2
South Carolina	12,454.9	560.0	2,394.3	5,561.5	311.2	1,492.3
Tennessee	13,965.0	556.8	1,393.0	1,468.9	93.3	336.6
Virginia	12,094.9	1,360.9	714.5	3,352.8	137.2	840.3
Total	180,713.7	10,651.5	34,369.3	58,852.2	3,594.0	19,450.6

Source: Data from Southern Region Forest Inventory and Analysis, http://www.srsfia.usfs.msstate.edu/.

South, then the conservation and restoration efforts of today will have been successful.

Needs for Additional Research

TNC's National Vegetation Classification System is the most important development for the study of natural plant communities in the last decade. This uniform, standardized method for classifying plant communities will provide a reliable means for comparing where we are with where we have been. Alternatively, efforts to model the current and projected distributions of plant communities or forest trees can substantially aid our understanding of the distribution of plant diversity throughout the South. For example, Prasad and Iverson (1999) have developed multiple maps of the current and projected distributions of 80 eastern forest trees based on a variety of sets of projected conditions.

Even though trained botanists have been exploring the Southern United States for over 300 years, the mapping of native plant communities has just begun. A full accounting of the variation and geography of species and their communities is critical. This information is essential to make an accurate assessment of the conservation needs of the region.

The greatest challenges to natural plant communities throughout the nation, but particularly in the South, are conversion to agriculture, the creation of tree plantations, and urbanization. The fourth common source of degradation of natural plant communities is the incursion of exotic invasive plant species. There is a great need to investigate more effective methods of control, whether chemical, biological, or physical. There are many safety concerns associated with chemical and biological control methods, but physical methods usually prove slow and expensive. It is impossible to eliminate exotic species from our region, but we can still take steps to reduce their impact on native plant communities and learn to better manage the impacts.

There is currently a management emphasis on the retention and development of old-growth forests, or forest stands with old-growth characteristics, on public land. However, concerns over the habitat needs of wildlife, especially migratory birds, has recently highlighted the broader need for forests with a range of structural traits. Early successional forest stands in particular support a very different array of native plant communities than do mature forests. There is a significant opportunity for research to contribute to a better understanding of the historical abundance and distribution of open areas in the South.

Finally, a future research priority for native plant communities should be restoration ecology. In the past, restoration has meant the establishment of any kind of vegetative cover on denuded landscape such as eroded farmland or strip mines. In the last decade, there has been a significant trend toward restoration of native communities using native plant material. However, the availability of native material is limited, and there is a growing concern about the source of the plant material used in restoration. We have much to learn about the distribution of genetic diversity in the native species commonly used for restoration, and even more to learn about the potential for use in restoration of the majority of plant species native to the South.

Acknowledgments

Figures 2.1 and 2.2 were developed by the Association for Biodiveristy Information (ABI), Natural Heritage Central Database, Arlington, VA (2001). Throughout the discussion in this chapter, work currently being accomplished by ABI has been attributed to its parent organization, The Nature Conservancy, for the sake of continuity. This chapter would not have been possible without the selfless work of thousands of professional and amateur botanists during the last 300 years. They have sweated and braved insects and briars to document, describe, and extol the flora of the Southeast. This chapter is dedicated to the thousands of young people who have yet to discover their love affair with botany.

Literature Cited

Abrams, M.D. 1992. Fire and the development of oak forests. Biosciences. 42: 346–353.

Anderson, M.; Bourgeron, P.; Bryer, M.T. [and others]. 1998. International classification of ecological communities: terrestrial vegetation of the United States. The national vegetation classification system: list of types. Arlington, VA: The Nature Conservancy. 502 p. Vol. II.

Association for Biodiversity Information. 2001. NatureServe. http://www.natureserve.org/. [Date accessed unknown].

Bailey, R.G. 1994. Ecoregions of the United States. Rev. ed. Washington, DC: U.S. Department of Agriculture, Forest Service. 1: 7,500,000; colored.

Bailey, R.G. 1998. Ecoregion map of North America. Misc. Publ.1548. Washington, DC: U. S. Department of Agriculture, Forest Service. 1: 15,000,000; colored.

Bartram, W. 1791. Travels through North and South Carolina, Georgia, east and west Florida, the Cherokee country, the extensive territories of the Muscogulges or Creek Confederacy, and the country of the Choctaws: containing an account of the soil and natural productions of those regions, together with observations on the manners of the Indians. Philadelphia: James and Johnson. 824 p.

Carrier, L. 1923. The beginnings of agriculture in America. New York: McGraw Hill. [Number of pages unknown].

Christensen, N.L. 1988. Vegetation of the southeastern Coastal Plain. In: Barbour, M.G.; Billings, W.D., eds. North American terrestrial vegetation. New York: Cambridge University Press. [Number of pages unknown].

Cowell, C.M. 1998. Historical change in vegetation and distribution on the Georgia Piedmont. American Midland Naturalist. 140: 78–89.

Croker, T.C., Jr. 1987. Longleaf pine: a history of man and a forest. For. Rep. R8–FR7. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. [Number of pages unknown].

Delcourt, H.R. 1979. Late Quaternary vegetation history of the Eastern Highland Rim and adjacent Cumberland Plateau of Tennessee. Ecological Monographs. 49: 255–280.

Delcourt, H.R. 1987. The impact of prehistoric agriculture and land occupation on natural vegetation. TREE. 2(2): 39–44.

Delcourt, H.R.; Delcourt, P.A. 1997. Pre-Columbian Native American use of fire on Southern Appalachian landscapes. Conservation Biology. 11: 1010–1014.

Delcourt, P.A.; Delcourt, H.R. 1993. Paleoclimates, paleovegetation, and paleofloras during the Late Quaternary. In: Flora of North America. New York: Oxford University Press. [Number of pages unknown]. Vol. 1.

Delcourt, P.A.; Delcourt, H.R. 1998. Paleoecological insights on conservation of biodiversity: a focus on species, ecosystems, and landscapes. Ecological Applications. 8: 921–934.

FLEPPC. 2001. Lists of Florida's invasive species. Florida Exotic Pest Plant Council. http://www.fleppc.org/. [Date accessed: July 2, 2002].

Greller, A.M. 1988. Deciduous forests. In: Barbour, M.G.; Billings, W.D., eds. North American terrestrial vegetation. New York: Cambridge University Press. [Number of pages unknown].

Grossman, D.H.; Faber-Langendoen, D.; Weakley, A.S. [and others]. 1998. International classification of ecological communities: terrestrial vegetation of the United States. The national vegetation classification system: development, status, and applications. Arlington, VA: The Nature Conservancy. [Number of pages unknown]. Vol. 1.

Kuchler, A.W. 1985. Potential natural vegetation. Rev. National atlas of the United States. Reston, VA: U.S. Geological Survey. 1: 7,500,000; colored.

Mac, M.J.; Opler, P.A.; Haecker, C.E.P.; Doran, P.D., eds. 1998. Status and trends of the Nation's biological resources. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey. [Number of pages unknown]. 2 vol.

Martin, P.S.; Klein, R.G., eds. 1984. Quaternary extinctions. Tucson, AZ: University of Arizona Press. [Number of pages unknown].

Milankovic, M. 1941. Canon of insolation and the ice-age problem. Royal Serbian Acad. Spec. Publ. 132. Belgrade: [Publisher unknown]. [Number of pages unknown].

Mitch, W.J.; Gosselink, J.G. 1993. Wetlands. New York: Van Nostrand Reinhold. [Number of pages unknown].

Noss, R.F.; LaRoe, E.T.; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biol. Rep. 28. Washington, DC: U.S. Department of the Interior, National Biological Service. [Number of pages unknown].

Nuttall, T. 1821. A journal of travels in the Arkansaw Territory during the year 1819. Philadelphia: T.H. Palmer. [Number of pages unknown].

Palmer, E.J. 1926. The ligneous flora of Hot Springs National Park and vicinity. Journal of the Arnold Arboretum. 7: 104–135.

Prasada, A.M.; Iverson, L.R. 1999. A climate change atlas for 80 forest tree species of the Eastern United States [Spatial database]. http://www.fs.fed.us/ne/delaware/atlas/index. Station [Date accessed: July 2, 2002].

Rabinowitz, D. 1981. Seven forms of rarity. In: Synge, H., ed. The biological aspects of rare plant conservation. New York: John Wiley. [Number of pages unknown].

Reveal, J.L.; Pringle, J.S. 1993. Taxonomic botany and floristics. In: Flora of North America. New York: Oxford University Press. [Number of pages unknown]. Vol.1.

Ricketts, T.H.; Dinerstein, E.; Olson, D.M. [and others]. 1999. Terrestrial ecoregions of North America: a conservation assessment. Washington, DC: Island Press. [Number of pages unknown].

Schlarbaum, S.E.; Hebard, F.; Spaine, P.C.; Kamalay, J.C. 1997. Three American tragedies: chestnut blight, butternut canker, and Dutch elm disease. In: Britton, K.O. Exotic pests of eastern forests: Proceedings of a meeting. Nashville, TN: Tennessee Exotic Pest Plant Council: 45–54.

Smith, E.B. 1994. Keys to the flora of Arkansas. Fayetteville, AR: University of Arkansas Press. [Number of pages unknown].

Stein, B.A.; Kutner, L.S.; Adams, J.S., eds. 2000. Precious heritage: the status of biodiversity in the United States. New York: Oxford University Press. [Number of pages unknown].

The Nature Conservancy. 1999. Ecoregional map of the United States. Arlington, VA. [Scale of map unknown]; colored.

University of Illinois. 1997. An introduction to the early cultures of the American bottom. http://www.ncsa.uiuc.edu/Cyberia/RiverWeb/History/Cahokia/. [Date accessed: July 2, 2002].

U.S. Department of the Interior, Fish and Wildlife Service. 2001. Species information: threatened and endangered animals and plants. http://endangered.fws.gov/wildlife.html#Species. [Date accessed: July 2, 2002].

Walker, L.C.; Oswald, B.P. 1999. The southern forest: geography, ecology, and silviculture. Boca Raton, FL: CRC Press. [Number of pages unknown].

Watts, W.A. 1971. Postglacial and interglacial vegetation history of southern Georgia and central Florida. Ecology. 52: 676–690.

Watts, W.A. 1980. The Late Quaternary vegetation history of the Southeastern United States. Annual Review of Ecology and Systematics. 11: 387–409.

Williams, G.W. 2000. The USDA Forest Service—the first century. Publ. FS–650. Washington, DC: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Woods, F.W.; Shanks, R.E. 1959. Natural replacement of chestnut by other species in the Great Smoky Mountains National Park. Ecology. 40: 349–361.

Wright, H.E., Jr. 1981. Vegetation east of the Rocky Mountains 18,000 years ago. Quaternary Research. 15: 113–125.

Wunderlin, R.P.; Hansen, B.F. 2000. Flora of Florida: pteridophytes and gymnosperms. Gainesville, FL: University Press of Florida. [Number of pages unknown]. Vol. 1.

What are the likely effects of expanding human populations, urbanization, and infrastructure development on wildlife and their habitats?

Chapter 3:
Human Influences on Forest Wildlife Habitat

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Key Findings

Impacts of Exotic Plants and Animals

■ Exotic plants and animals have had a documented impact on forest wildlife and habitats. Exotic species threaten the survival of some sensitive wildlife species.

■ Some forest wildlife species have benefited from exotic species, but indiscriminant use of exotic species for wildlife management purposes in the past has led to serious problems.

■ Of the exotic species introduced into this country, only 4 to 19 percent have caused great harm. Another 6 to 53 percent have neutral or as yet undetermined effects.

■ Approximately 42 percent of species that are listed in the United States as threatened or endangered under the Endangered Species Act are at risk because of competition with or predation by exotic species.

■ More effective programs for preventing the introduction and establishment and spread of exotic species are needed. Protection and recovery of native species and ecosystems should be included as a goal in programs for control and management of exotic species.

Land Use Changes in Forested Habitats

■ Urban and agricultural land uses have interrupted the continuity of southern forests and created forest islands. Wildlife species differ in their response to the resulting fragmentation.

■ Some wildlife species, particularly habitat specialists, have been harmed by loss and degradation of forest habitat and population isolation caused by urbanization and agriculture.

■ Other forest wildlife species have benefited from the creation of edge habitat and have adjusted to the new habitats created by people. Habitat generalists tend to adjust more easily to changes brought about by urbanization.

■ Urbanization excludes some sensitive forest wildlife species but increases the presence of others. Urban habitats vary in their ability to support a diversity of forest wildlife. Advance planning and careful management can enhance the habitat value of urban and suburban conservation areas.

■ For the most part, wildlife species that are tolerant of urbanization are not the rare or declining species that are of management concern.

■ For species with area sensitivities, those that require forest interior, those that require specialized habitats, and those intolerant of human disturbance, special management considerations will be needed as urbanization increases in areas of the South.

■ Prior to European settlement, early successional and disturbance-dependent birds were found in naturally occurring and Native American-maintained forest openings. Many of these disturbance-maintained ecosystems have been lost from the landscape during the last 300 years.

■ The value of agricultural areas in providing habitat for early successional wildlife species (such as bobwhite) depends largely on how they are managed. “Clean farming,” loss of pastures, creation of fescue-dominated pastures, and the use of heavy, fast-moving machinery have reduced the value of the habitat formerly found in pastures and agricultural fencerows.

■ Agricultural crops provide foraging habitat for some forest wildlife, such as deer, black bears, raccoons, and many bird species.

■ Woody fencerows enhance the habitat value of agricultural areas for some wildlife and facilitate the movement of other forest wildlife species. However, woody fencerows in grassland habitats can reduce the habitat value to grassland-dependent birds due to increasing predator presence.

■ Abandoned agricultural fields in the South have provided important old-field habitat for some early successional and disturbance-dependent wildlife species. This abandonment trend is diminishing in many areas of the Southeast, but forecast abandonment of agricultural lands in the Western portion of the region may provide at least a temporary benefit for early successional species.

■ Successful conservation of some forest bird species will likely require forest management areas with thousands of acres of contiguous forest habitat. Similarly, many early successional and disturbance-dependent bird species are also area-sensitive, requiring hundreds of acres for successful conservation of some grassland bird species and dozens of acres for some scrub-shrub birds.

■ The area-sensitivities documented for many forest bird species must be considered in a landscape context. Forest patch size is of greater concern in fragmented landscapes, such as the ridge and valley province of the Appalachians and the Mississippi Alluvial Plain, than in predominantly forested landscapes, such as heavily forested areas of the southern Blue Ridge and Cumberland Plateau and the Ozark-Ouachita Highlands.

Linear Land Uses (Roads, Power Lines, and Trails)

■ The effects of linear land uses (roads and utility rights-of-way) on forest birds should be considered in a landscape context. A continuum of effects has been documented, depending on the percent of the landscape forested, the road type and width, the maintenance needs, and other site-specific factors.

■ Linear corridors, such as roads and power lines, can exclude sensitive forest wildlife from the adjoining habitat for distances ranging up to 330 feet or more. Effects on sensitive forest birds are of more concern in fragmented landscapes.

■ In largely forested landscapes, roadsides and power line corridors can provide important habitat for some grassland and early successional bird species with less concern required for the negative effects often attributed to fragmentation.

■ Linear corridors act as barriers to the movement of some wildlife species, fragmenting populations. Examples include road effects on woodland mice, interstate highway effects on black bears, and power line effects on some neotropical migrants. Negative impacts documented for neotropical migrants as a result of fragmentation (such as reduced reproductive success in small forest patches) are of greater concern in heavily fragmented landscapes, however.

■ Linear corridors act as travel lanes for other wildlife, such as grassland or scrub-shrub birds in largely forested landscapes, connecting isolated areas of habitat.

■ Roadsides and power line corridors facilitate the spread of exotic plants and animals. Many exotics have been slower to gain a foothold in predominately forested landscapes.

■ Road mortality has been well documented for many wildlife species, but the extent of the problem varies with a number of parameters, including traffic speed and volume, road type, extent of cleared rights-of-way, wildlife species present, and season. Road-related mortality is a serious problem for some rare species, such as the endangered Florida panther and the endangered Key deer.

■ Sensitive forest plant species can be negatively impacted by human use of forest trails. “Collectable” wildlife may become rare along trails.

Introduction

Effects of Exotic Species on Forest Wildlife and Wildlife Habitat

Exotic nonnative plants and animals were introduced into this country either intentionally or accidentally. In addition, many native species have been accidentally or intentionally introduced to other regions of the country, sometimes with negative consequences. The latter group will not be discussed in this chapter. Since European colonization, thousands of plants and animals have been intentionally introduced into the United States. Many of these introductions have been beneficial to humans. Nonindigenous crops and livestock are the foundation of U.S. agriculture (U.S. Congress, Office of Technology Assessment 1993). Other exotic species are mainstays of horticulture and the pet and aquarium industries: others are used successfully for soil erosion control and biological control. Of the introduced species, only a relatively few cause great harm. The U.S. Congress, Office of Technology Assessment, estimates 4 to 19 percent of exotic species fall into this category. Another 6 to 53 percent are estimated to have neutral or unknown effects. Many of our most invasive exotic species have been introduced into an environment in which they did not evolve and in some cases they have few or no natural enemies. Once established, they reproduce and spread unimpeded by (and often at the expense of) native plants and animals.

Human Land Use Changes and Forest Wildlife

Following European settlement, historic trends in southern forest wildlife have closely followed habitat changes associated with land conversion and timber resource removal, coupled with uncontrolled exploitation of many species. For a more detailed history of southern forest wildlife see chapter 1. Alterations in land use have changed the amounts of forest habitat available to forest wildlife species. They have fragmented forest stands and changed forest edge and forest interior habitats. Changes in the abundance, species richness, and species composition of forest wildlife have been documented in response to land use changes. This section describes the responses of forest wildlife to human land use changes.

See chapters 6 and 24 for a more detailed discussion of historic land use changes. The initial conversion of forests and forest openings to farmland brought many changes in the numbers and kinds of wildlife (Bolen and Robinson 1995). Land conversions were not always negative for wildlife, however. Timber cutting for homesteads, cooperage, tanbark, heating, and land conversion (for fields and livestock) was initially beneficial to many wildlife species (Clark and Pelton 1999). Small farms carved from forests offered more edge habitat and supplemental food sources for many wildlife species. As forest timbering and land use conversions increased, however, a combination of habitat loss and unrestricted wildlife exploitation decimated populations of black bears, white-tailed deer, and turkeys (Adams 1994, Clark and Pelton 1999).

Later, a trend toward abandonment of the small farms carved into wood-lands began as the soils were depleted (chapter 6). As previously tilled lands reverted to shrubs and other vegetation, white-tailed deer, eastern cottontails, northern bobwhite, and some early successional bird species were highly favored (Clark and Pelton 1999, Hunter and others 2001b). The conversion of agricultural land to some type of forest cover is expected to continue in some areas of the South as landowner returns from agriculture decline relative to those from forestry (chapter 6). Recent changes in farming practices have reduced the value of farms as habitat for some wildlife species.

Currently, strong economic growth has led to increased urbanization in parts of the South (chapter 6). Urbanization fragments the natural landscape, destroys habitat required for many species, modifies habitat for others, and creates new habitat for some species (Adams 1994). This land use shift will continue to influence the region's forests along with forest wildlife and habitat (chapter 6). Recent patterns of urban growth in the South have moved more people into the historically rural areas in low-density residential developments. In some areas of the South, forest cover remains relatively high, but the landscape is highly fragmented. Land use changes that result in increased forest fragmentation could have negative impacts on a number of forest wildlife species, including many mature forest and early successional bird species.

Linear Land Uses (Roads, Power Lines, and Trails)

Along with urbanization, linear human land uses, such as roads and power lines, are increasingly prevalent in the South. The mortality of wildlife due to vehicle collisions and forest habitat loss are the most obvious impacts of roads on forest wildlife, but an increasing body of information suggests that the effects on wildlife populations are much more complex. About 3.85 million miles of public roads now exist in the United States (Forman 2000). Based on an assumption that some of the ecological effects of roads extend outward for more than 330 feet, Forman estimates that about one-fifth of the U.S. land area is directly affected ecologically by the system of public roads. Several compilations and review papers on the ecological effects of roads are available (Findlay and Bourdages 2000, Forman and Deblinger 2000, National Resources Defense Council 2000, Trombulak and Frissell 2000).

Similarly, power line corridors function in a variety of ways to affect forest wildlife populations. Knight and Kawashima (1993) estimated that there were more than 0.31 million miles of power lines in the United States, covering an estimated 5.2 million acres of land.

Trails also are linear features that bisect forest habitats and can affect sensitive forest plants and wildlife. Outdoor recreation activities are growing in popularity throughout the United States (Miller and others 1998), and recreational opportunities in the South are increasingly concentrated on the relatively small percentage of forested public land (chapter 11). More information about outdoor recreation in southern forests can be found in chapter 11.

Methods

To describe the documented effects of introduced exotic species, human land use changes, and infrastructure development on forest wildlife, information was incorporated from available scientific literature and the World Wide Web.

Data Sources

Sources of information used for compiling this chapter are cited in the text and details about these references can be found in Literature Cited.

Results

Effects of Exotic Species on Forest Wildlife and Wildlife Habitat

Exotic plant pathogens and forest wildlife—More than 20 species of exotic plant pathogens have been introduced into forests in the United States (Pimentel and others 1999), and exotic forest pests have greatly altered the species composition of forests in the East (Campbell 1997). Some tree species, important as sources of timber, other products, wildlife food, or other ecological services, have been virtually eliminated throughout their ranges or greatly reduced in numbers in large portions of their ranges. The loss of nuts and berries formerly produced by vanishing or severely reduced tree species has had a poorly documented but surely substantial impact on wildlife species of the forest (Campbell 1997). See chapter 17 for a complete discussion of forest timber pathogens and diseases. Although the impacts of exotic plant pathogens to timber resources are well documented, the impacts on forest wildlife resources are not well described.

At the beginning of the 1900s, the American chestnut was one of the most important wildlife plants of the Eastern United States (Martin and others 1951). With this tree practically exterminated by the exotic chestnut blight, mast-dependent forest wildlife, such as white-tailed deer and black bears, had to settle for inconsistent acorn and hickory nut crops as their primary food (Clark and Pelton 1999). The blight almost certainly reduced the carrying capacity of southern highland habitats for mast-dependent wildlife. Hard mast output may have been reduced as much as 34 percent following the loss of chestnuts (Diamond and others 2000). The blight is thought to have caused at least five indigenous insect species to become extinct or extremely rare (U.S. Congress, Office of Technology Assessment 1993). In areas where resprouting chestnuts remain in the understory, birds and mammals continue to transport virulent and hypovirulent-like strains of chestnut blight fungus (Scharf and DePalma 1981). Chinquapins in southern forests (including the Allegheny and Ozark chinquapins) vary in their susceptibility to chestnut blight. The chinquapins may not match the former value of the American chestnut in their habitat contribution to wildlife in southern forests (Martin and others 1951), but the nuts they produce are valuable to wildlife (U.S. Department of Agriculture, Forest Service 1999). Chestnut blight has affected chinquapins in southern forests and is expected to continue reducing the prevalence of susceptible tree species. However, no extermination of any southern wildlife species has been documented in conjunction with chinquapin losses.

Dutch elm disease devastated American elms as it spread across most of the country. In areas where Dutch elm disease removed the elm trees from the forest canopy, bird population surveys documented high local extirpation and colonization rates by bird species during the early 1950s (Whitcomb and others 1981). In Great Britain, reductions in bird abundance and diversity were documented in wooded farmlands accompanying elm death from Dutch elm disease and subsequent felling of dead trees (Osborne 1982, 1983, 1985). The combination of Dutch elm disease and logging reduced the availability of suitable nesting cavities for cavity-nesting waterfowl species (Johnsen and others 1994).

Other exotic plant pathogens continue to affect wildlife habitat in southern forests by reducing the abundance of valuable forest tree species. These include dogwood anthracnose and butternut canker. Flowering dogwoods are valuable to many wildlife species for their fruit production (Martin and others 1951; U.S. Department of Agriculture, Forest Service 1999). Butternuts are consumed by many species of forest wildlife.

Exotic plant invaders and forest wildlife—Some troublesome weed pests (such as Johnsongrass, multiflora rose, and kudzu) were intentionally introduced as crops for wildlife enhancement or for erosion control, but later became pests (Pimentel and others 1999). The majority of weeds, however, were accidentally introduced with crop seeds from ship-ballast soil or from various imported plant materials, such as ornamental plants. Some exotic invasive plants, such as Chinese privet, are shade tolerant and once established are capable of invading relatively dense forests. Many other invasives, such as kudzu, mimosa tree, or princess tree, are less adept at colonizing deeply shaded, mature forests except along edges, in natural or artificial forest canopy openings, or in disturbed or fragmented forests. Exotic plants have been spread by overgrazing, land use changes, application of fertilizers, and the use of agricultural chemicals (Westbrooks 1998). Other human activities result in disturbed environments and encourage invasive plants. These activities include farming, creation of highway and utility rights-of-way, clearing land for homes and recreation areas, such as golf courses, and constructing ponds, reservoirs, and lakes.

Millions of acres of forest land in the Southeast are occupied by exotic invasive plants. For many species, the acreage infested and spread rates are unknown. Kudzu and Japanese honeysuckle occupy more than 7 million acres each, and their spread rates are increasing (Miller 1997). Clearcuts in the South can become infested with exotic vines, such as Japanese honeysuckle and mile-a-minute, which can prevent the growth of seedlings and retard timber yields (Campbell 1997, Nuzzo 1997). English ivy and Japanese honeysuckle can overgrow and eventually kill trees and understory plants and have fundamentally altered the character and structure of some forests (U.S. Congress, Office of Technology Assessment 1993). The herbaceous or shrub layers of large but unrecorded areas of forest are being transformed into virtual monocultures by exotic vines, herbs, and shrubs. In some cases, these plant invasions have been shown to reduce forage or cover for wildlife (Campbell 1997). Table 3.1 lists some exotic plant species that are particularly noxious in forests in the Southern United States.

In recent years the impact of invasive exotics on biodiversity has become a major concern. Biological invasions

Table 3.1—Exotic invasive plants of southern forests

Common name	Scientific name	Plant description
Silktree or mimosa tree	*Albizia julibrissin*	Tree
Chinaberry	*Melia azedarach*	Tree
Tallowtree or popcorn tree	*Sapium sebiferum*	Tree
Tree of heaven or stinktree	*Ailanthus altissima*	Tree
Empress or princess tree	*Paulownia tomentosa*	Tree
Bicolor lespedeza	*Lespedeza bicolor*	Shrub
Burning bush	*Euonymus alatus*	Shrub
Japanese privet	*Ligustrum japonicum*	Shrub
Chinese privet	*Ligustrum sinense*	Shrub
Common privet	*Ligustrum vulgare*	Shrub
Multiflora rose	*Rosa multflora*	Shrub
Autumn olive	*Elaeagnus umbellata*	Shrub
Amur or bush honeysuckle	*Lonicera maackii*	Shrub
Japanese barberry	*Berberis thunbergii*	Shrub
Japanese honeysuckle	*Lonicera japonica*	Vine
Japanese climbing fern	*Lygodium japonicum*	Vine
English ivy	*Hedera helix*	Vine
Kudzu	*Pueraria montana*	Vine
Mile-a-minute	*Polygonum perfoliatum*	Vine
Periwinkle	*Vinca minor*	Vine
Oriental bittersweet	*Celastrus orbiculatus*	Vine
Chinese wisteria	*Wisteria sinensis*	Vine
Winter creeper	*Euonmus fortunei*	Vine
Cogongrass	*Imperata cylindrica*	Grass
Japanese grass or stiltgrass	*Microstegium vimineum*	Grass
Johnsongrass	*Sorghum halepense*	Grass
Tall fescue	*Fescue elatior*	Grass
Common teasel	*Dipsacus sylvestris*	Herb
Crown vetch	*Coronilla varia*	Herb
Garlic mustard	*Alliaria petiolata*	Herb
Japanese knotweed	*Polygonum cuspidatum*	Herb
Musk thistle	*Carduus nutans*	Herb
Purple loosestrife	*Lythrum salicaria*	Herb
Sericea or Chinese lespedeza	*Lespedeza cuneata*	Herb
Spotted knapweed	*Centaurea maculosa*	Herb
Sweet clover	*Melilotus alba*	Herb

Source: Miller 1997, USDA Forest Service 1999, Rural Action Inc. 1999.

by exotic species may displace native animals and plants, disrupt nutrient and fire cycles, and change the patterns of plant succession (Westbrooks 1998). Invasive exotic plants encroach into parks, preserves, wildlife refuges, and urban areas. Since many of these areas are significant for maintaining indigenous animals and plants (U.S. Congress, Office of Technology Assessment 1993), the responsible land management agencies are forced to expend increasing resources to control the most troublesome invaders. Approximately 61 percent of our national parks have at least a moderate level of exotic plant infestation: severely impacted parks include the Great Smoky Mountains. An estimated 400 of 1,500 vascular plant species in the Great Smoky Mountains National Park are exotic, and 10 of these are currently displacing and threatening other species in the park (Pimentel and others 1999). Invasive exotic species are considered to be the second most important threat to biodiversity, after habitat loss and degradation. Approximately 42 percent, or about 400, of the 958 species that are listed in the United States as threatened or endangered under the Endangered Species Act are at risk because of competition with or predation by exotic species (Wilcove and others 1998). In south Florida, exotic plant species, such as Australian pine, Brazilian pepper, and leatherleaf fern, are invading disturbed areas and outcompeting native vegetation, reducing Key deer foods and habitat (U.S. Fish and Wildlife Service 1999). In spite of the severity of exotic plant invasion in southern forests, the impacts to forest wildlife in the South have only been sparsely documented. More information about the effects of exotic invasive plants on forest ecosystems can be found in chapter 2.

Exotic plant invaders and forest wildlife: use of exotic plant species by insect herbivores—

Many exotic invasive plant species lack insect herbivores adapted to live and feed on them. This factor likely contributes to their rapid spread. The number of plant-feeding insects associated with various trees is a reflection of the cumulative abundance of that tree throughout geological history (Southwood 1961). Recently introduced exotic tree species generally support relatively few insect species compared to abundant native tree species. The Chinese tallow tree is an invasive exotic that has spread rapidly across the Southern United States. Insects likely control the spread of this tree in its native China, and the lack of insect predation has aided its spread in the United States. Only one species, the leaf-footed bug, has been reported causing fruit damage to this exotic tree (Johnson and Allain 1998).

Exotic plant invaders and forest wildlife: use of exotic plant species by forest wildlife—

Despite the tendency of some exotic plant invaders to form dense monocultures that exclude native flora and fauna, many species of southern wildlife use exotic plant species for forage and cover. Indeed, some invasive plant species in southern forests were introduced because they were considered beneficial for wildlife habitat (Miller 1997). For instance, multiflora rose was promoted in the 1930s by the U.S. Soil Conservation Service for erosion control and as living fences for livestock (Plant Conservation Alliance – Alien Plant Working Group 2002). Soon after, however, state conservation agencies promoted its value as wildlife cover for pheasants, bobwhite quail and cottontail rabbits, and as food for songbirds. These agencies encouraged its use by distributing free rooted cuttings to landowners. Other exotic plants that were at one time promoted by government agencies or private groups for wildlife cover or food sources include Japanese honeysuckle, exotic bush honeysuckles (including Amur honeysuckle), Chinese lespedeza, bicolor lespedeza, and Chinese privet (Miller 1997, Plant Conservation Alliance – Alien Plant Working Group 2002, Virginia Natural Heritage Program 2002).

The value of Japanese honeysuckle both as cover and a food source for songbirds, gamebirds, hummingbirds, small mammals, and deer has been documented (Hugo 1989, Martin and others 1951, Miller 1997). Other exotic honeysuckles, such as Amur honeysuckle, also have been documented as food and cover for birds and small mammals (Martin and others 1951, Whelan and Dilger 1992, Williams and others 1992).

Multiflora rose is an invasive exotic shrub that was widely promoted by conservation agencies in the 1930s for cover, wildlife food, and as living fences (Miller 1997). It provides excellent habitat for gamebirds and songbirds (Martin and others 1951, Morgan and Gates 1982) and for cottontail rabbits (Morgan and Gates 1983).

Japanese and Chinese privets are invasive exotic shrubs that can replace native understory species and prevent forest regeneration in riparian forests and bottomland hardwood-pine forests (Miller 1997). Privets are used for food and habitat by birds, and their seeds are widely dispersed by birds (Martin and others 1951, Miller 1997). Chinese privet also has been documented in northwestern Georgia as an important component of fall and winter diets of the white-tailed deer (Stromayer and others 1998).

Exotic shrubs in the buckthorn family provide excellent nesting and feeding habitat for many species of songbirds (Whelan and Dilgar 1992). The exotic shrub bicolor lespedeza provides food for songbirds, gamebirds, and hooved browsers, including white-tailed deer (Martin and others 1951, Miller 1997).

The Chinese tallow tree in coastal South Carolina is used heavily by more than 14 bird species (Renne and others 2000). The Russian olive provides feeding habitat for songbirds, gamebirds, and hooved browsers (Martin and others 1951). Chinaberry is eaten to a limited extent by songbirds (Martin and others 1951).

Although these exotic invasive plant species provide habitat and food for southern wildlife species, no scientific investigations were found that compared the relative habitat value of these exotic invaders to the native flora that they displaced. In addition, no scientific investigations were found that documented the effects of exotic plant species invasions on a broad spectrum of southern forest wildlife species, including sensitive habitat specialists. The past introduction of exotic plants for wildlife management has unintentionally led to severe invasive exotic species problems. Many of the intended habitat benefits of these invasive species can be found in carefully selected native species. See the National Park Service Web site at http://nps.gov/plants/alien/fact.htm for some suggested native plant alternatives. Introduction of exotic plant species for wildlife enhancement should be approached with caution to avoid future invasive species problems.

Effects of exotic animals on forest wildlife: exotic insect pests and forest wildlife—More than 2,000 arthropod species and 11 earthworm species have been introduced into the Continental United States, including approximately 500 exotic insect and mite species (Pimentel and others 1999). About 360 exotic insect species have become established in American forests and approximately 30 percent of these species have become serious pests. Although the negative effects of invertebrate pest species, such as the gypsy moth and the balsam woolly adelgid, to southern forests have been well documented (see chapter 17), much less information is available about their effects on wildlife. See chapter 17 for a description of the effects of insects and other forest pests on southern forests.

Balsam woolly adelgid—The balsam woolly adelgid is an aphid that inflicts severe damage in balsam-fir forests (Pimentel and others 1999). The balsam woolly adelgid has killed up to 95 percent of the Fraser firs in the Southern Appalachians.

Resultant habitat losses have impacted forest wildlife. A few species, such as the larvae of the moth *Semiothisa fraserata*, may depend exclusively on the Fraser fir for food (Stein and Flack 1996). Other species, such as the Weller's salamander, are endemic to the spruce-Fraser fir habitat of the Southern Appalachians. Changes in the avifaunal composition of Fraser fir forests were documented in the Southern Appalachians following destruction of the Fraser fir canopy by the balsam woolly adelgid (Alsop and Laughlin 1991, Rabenold and others 1998).

Frazier fir bark provides substrate for eight rare species of mosses and liverworts (Stein and Flack 1996). The endangered spruce-fir moss spider lives in moss mats that are only found in the spruce-Fraser fir forests of Southern Appalachia (U.S. Fish and Wildlife Service 1998). Loss of the tree canopy (due to the balsam woolly adelgid) has resulted in increased light and temperature and decreased moisture on the forest floor, causing the moss mats on which the spider depends to dry up and become unsuitable.

The endangered Virginia northern flying squirrel and the endangered Carolina northern flying squirrel are found in conifer-hardwood ecotones or forest mosaics of spruce-fir associated with various hardwoods in high elevations of the Southern Appalachians (U.S. Fish and Wildlife Service 1990a). Although decimated by past logging of spruce forests, these two subspecies are currently threatened by several factors including habitat damage to conifer-hardwood ecotones by the balsam woolly adelgid and gypsy moth.

Gypsy moth—The gypsy moth was accidentally released in Medford, MA, in 1869. The spread rate of gypsy moths from 1966 through 1990 was approximately 13 miles per year (Liebhold and others 1995). Gypsy moths feed on numerous trees, shrubs, and vines but prefer oaks (U.S. Department of Agriculture, Forest Service 1999).

Infestation by gypsy moths can impact forest wildlife habitat in several ways. Severe infestations can reduce the production of acorns and mast produced by susceptible tree species, reducing mast available for wildlife. However, resultant dead trees can serve as dens for some wildlife (Brooks and Hall 2000). Defoliation of the overstory can displace closed-canopy bird species, while increasing the abundance of open-canopy species (Michigan State University 1997). In some heavily overstocked forests lacking natural disturbances (such as fire), defoliation can benefit forest birds dependent upon smaller openings in mature hardwood or mixed forests. Beneficiaries include some declining or priority species, such as Canada warblers and white-throated sparrows (Hunter and others 2001b).

Following gypsy moth infestations, sensitive shade-dependent understory plants can become stressed by the increased sunlight reaching the forest floor (U.S. Department of Agriculture, Forest Service 1999). Defoliation of the overstory increases the growth of shrubs, grasses, and herbs providing some wildlife with additional cover and forage (Brooks and Hall 2000).

Red imported fire ants—The red imported fire ant infests more than 250 million acres in the United States (Allen and others 1994). Fire ants could spread across almost a quarter of the Nation before range limits are reached. Southern States already infested by the species suffer damages totaling more than $1 billion per year (Pimentel and others 1999).

Red imported fire ants are most abundant in open habitats with disturbed soil, where sunlight can reach the soil surface (Stiles and Jones 1998). They are rare in shaded or undisturbed habitats, such as intact forests. Fire ants can invade southern forests along the margins of linear disturbances, such as roads or power lines. In areas where the red imported fire ant is abundant, native ants are displaced by competition. Although omnivorous, the species feeds voraciously on living and dead insects. Native arthropod diversity and abundance often are reduced in heavily infested areas (Allen and others 1994, Stiles and Jones 1998, Tedders and others 1990).

Red imported fire ants have had detrimental impacts on many wildlife species (Allen and others 1994). Reptiles and amphibians tend to be vulnerable to displacement by fire ants when they compete for shared prey (invertebrates) or have an egg stage vulnerable to predation during times of high fire ant activity. Fire ants have been documented to destroy nests and cause hatchling mortality of the threatened gopher tortoise (Allen and others 1994, U.S. Fish and Wildlife Service 1990b).

Fire ants compete with native scavengers that feed on dead animals and fallen fruit. They have been implicated in declines of ground-nesting birds, such as quail and turkey, because they attack newly hatched young (U.S. Department of Agriculture, Forest Service 1999). Nest and chick predation by the red imported fire ant has been documented for many bird species (Allen and others 1994). The red imported fire ant has been linked to declines of migratory wintering populations of the loggerhead shrike (Grisham 1994). Injuries or death to white-tailed deer fawns and other newborn small mammals due to attack by the red imported fire ant have been widely reported (Allen and others 1994).

Effects of exotic animals on forest wildlife: effects of exotic wildlife on native forest wildlife—Stein and Flack (1996) estimate that at least 2,300 species of exotic animals now inhabit the United States. This total includes an estimated 20 species of exotic mammals, 97 species of exotic birds, and 53 species of exotic reptiles and amphibians. These species cost the U.S. economy about $27.5 billion every year (Pimentel and others 1999, Scientific American 1999). Many of the larger exotic animals were deliberately imported for aesthetic, sport hunting, or livestock purposes. Deliberate imports include European starlings, European wild boars, ring-necked pheasants, and feral pigs. Other smaller exotic pests, such as rats, mice, red imported fire ants, and balsam woolly adelgid, arrived hidden in cargo holds, shipping containers, produce, and imported forest products. Echternacht and Harris (1993) indicated that at least 50 exotic wildlife species have become established in the Southeastern United States comprising about 8 percent of the 625 native and exotic wildlife species. Table 3.2 is based on their wildlife and faunal description. It contains a list of exotic wildlife species that inhabit southern forests.

Feral pigs—Feral pigs that descended from domestic farm animals and European wild boars that were introduced for sport hunting now number about 4 million across the United States. Together, they cost the economy more than $800 million in damages per year (Pimentel and others 1999). Florida has about 0.5 million and Texas has 1 to 1.5 million.

The effects of wild pigs vary greatly from place to place, depending on the density of pigs and the sensitivity of the ecosystems involved (Singer 1981). Their rooting habit has damaged sensitive forest habitats across the South, including rare wetlands and springs in the Ozark-Ouachita Highlands (U.S. Department of Agriculture, Forest Service 1999). Wild pigs compete with wild turkeys and white-tailed deer for acorns and other foods. They tear up rotten logs that provide habitat for many amphibians and reptiles. In addition, hogs destroy the nests of turkeys, ruffed grouse, and other ground-nesting birds (Miller and Leopold 1992, Sealander and Heidt 1990). Wild pigs also carry diseases, such as brucellosis and pseudorabies that represent a risk to native wildlife (New and others 1994, Peine and Lancia 1990, Tozzini 1982). No antibodies for serious diseases were detected in a 1990 survey of wild pigs in the Great Smoky Mountain National Park, however (New and others 1994).

Wild pigs occur in 13 national parks but are especially problematic in the Great Smoky Mountains National Park (Singer 1981). Wild boars invade high-elevation northern hardwood communities from about April through August where their rooting has reduced understory plant cover up to 87 percent. Up to 77 percent of all logs and branches are moved in heavily rooted areas. Red-backed voles and shrews are normally common in pristine stands, but are absent in rooted areas.

Feral cats—Domestic cats, including both pets and free-ranging animals, now number about 100 million in the United States (Coleman and others 1997). The occurrence of cats tends to be concentrated around areas of human habitation. Studies of free-ranging domestic cats indicate that small mammals comprise about 70 percent of their prey, and birds constitute about 20 percent. Nationwide, free-ranging rural cats probably kill more than a billion small mammals and hundreds of millions of birds each year. Free-ranging cats are a serious threat to ground-nesting birds, such as turkey and quail (Miller and Leopold 1992; U.S. Department of Agriculture, Forest Service 1999), and also attack shrub-nesting songbirds. In Florida, free-ranging cats are contributing to the imperiled status of several federally listed species, including the Lower Keys marsh rabbit, several types of beach mice, and woodrats.

Free-ranging cats can outnumber and compete with native predators, including hawks and weasels (Coleman and others 1997). Cat predation may deplete winter populations of microtine rodents and other prey of red-tailed hawks, marsh hawks, and American kestrels (George 1974). Free-ranging cats also can potentially transmit new diseases to forest wildlife, including feline leukemia to cougars (Jessup and others 1993) and feline distemper and feline immunodeficiency virus to the endangered Florida panther (Roelke and others 1993).

Feral dogs—Free-ranging and feral domestic dogs are nearly ubiquitous across the United States (Drost and Fellers 2000); many problems are reported in Florida and Texas (Pimentel and others 1999). Free-roaming dogs

Table 3.2—Introduced terrestrial wildlife species in southern forests

Common name	Scientific name	Animal description
Cuban treefrog	*Osteopilus septentrionalis*	Amphibian
Greenhouse frog	*Eleutherodactylus planirostris*	Amphibian
Brown anole	*Anolis sagrei*	Reptile
Ring-necked (green) pheasant	*Phasianus colchicus*	Bird
Plain chacalaca	*Ortalis vetula*	Bird
Rock dove	*Columba livia*	Bird
Rose-ringed parakeet	*Psittacula krameri*	Bird
Budgerigar	*Melopsittacus undulatus*	Bird
Canary-winged parakeet	*Brotogeris versicolurus*	Bird
Monk parakeet	*Myiopsitta monachus*	Bird
European starling	*Sternus vulgaris*	Bird
Spot-breasted oriole	*Icterus pectoralis*	Bird
House sparrow	*Passer domesticus*	Bird
Rhesus macaque	*Macaca mulatta*	Mammal
Black rat	*Rattus rattus*	Mammal
Norway rat	*Rattus norvegicus*	Mammal
House mouse	*Mus musculus*	Mammal
Wild boar	*Sus scrofa*	Mammal
Fallow deer	*Cervus dama*	Mammal
Sambar deer	*Cervus unicolor*	Mammal

Source: Echternacht and Harris 1993, Choate and others 1994.

chase and harass indigenous wildlife (Sealander and Heidt 1990; U.S Congress, Office of Technology Assessment 1993) and disturb ground-nesting birds, such as quail and wild turkeys, by attacking adult birds and consuming eggs and hatchlings (Miller and Leopold 1992; U.S. Department of Agriculture, Forest Service 1999). In southeast Alabama, free-ranging dogs prey upon the threatened gopher tortoise and destroy gopher tortoise burrows (Causey and Cude 1978, U.S. Fish and Wildlife Service 1990b). In south Florida, dog-related deaths are the second most frequent cause of human-induced mortality for the endangered Key deer (U.S. Fish and Wildlife Service 1999).

Free-ranging dogs have the ability to interbreed with coyotes and the federally endangered red wolf (Sealander and Heidt 1990; U.S. Department of Agriculture, Forest Service 1999).

European starlings—After the introduction of European starlings in the late 1800s, population growth and range expansion were explosive. Starling populations now appear to have leveled off or are decreasing in most areas across the country (Robbins 2001). Although starlings consume noxious insects and weed seeds, they also compete with native species for food and nesting cavities. Displacement of native birds by starlings has been documented in areas of the country with limited nest sites (Weitzel 1988). Starlings are known to be a very aggressive species when competing for or usurping cavities from other birds (James and Neal 1986).

Effects on reproduction and fecundity of red-bellied woodpeckers were documented due to nest cavity competition with starlings (Ingold 1994, 1996; Ingold and Densmore 1992). The effects of starling nest cavity competition on northern flickers and red-headed woodpeckers were found to be less severe. Competitive cavity losses for red-headed and northern flickers have more serious implications, however, since these two species are currently declining. Starlings are common in urban and agricultural woods, but are seldom found in densely forested areas (Ingold and Densmore 1992). Red-bellied woodpeckers that nest in more heavily wooded environments are more successful in avoiding competition with starlings. Starlings also compete with other native birds, including the eastern bluebird and purple martin, for cavity nest sites (U.S. Department of Agriculture, Forest Service 1999).

House sparrows—Following a series of introductions in the United States, house sparrows became well established across the continent by 1910. Currently, populations appear to be stable or decreasing in most areas of the country (Robbins 2001). House sparrows are found mainly in urban and agricultural areas (James and Neal 1986) and are seldom found in predominantly forested areas.

Although they commonly nest in man-made structures, house sparrows also use deteriorating nests of other species, woodpecker cavities, and nesting boxes intended for other species. House sparrows have been documented to usurp cavities from red-bellied and red-headed woodpeckers (Ingold and Densmore 1992). In addition to native woodpeckers, house sparrows have been known to harass

Table 3.3—Some southeastern forest bird species and their sensitivities to urban and suburban development

Common name	Scientific name	Urban/suburban association
Mature-forest assemblage (late successional forests)		
Pine warbler	*Dendroica pinus*	Tolerant
Red-eyed vireo	*Vireo olivaceus*	Intolerant
Red-bellied woodpecker	*Melanerpes carolinus*	Tolerant
Wood thrush	*Hylocichla mustelina*	Intolerant
Ovenbird	*Seiurus aurocapollus*	Intolerant
Hooded warbler	*Wilsonia citrina*	Intolerant
Acadian flycatcher	*Empidonax virescens*	Intolerant
Scarlet tanager	*Piranga olivacea*	Intolerant
Northern parula	*Parula americana*	Intolerant
Black-and-white warbler	*Mniotilta varia*	Intolerant
Hairy woodpecker	*Picoides villosus*	Tolerant
Pileated woodpecker	*Dryocopus pileatus*	Intolerant
Yellow-throated warbler	*Dendroica dominica*	Intolerant
Prothonotary warbler	*Protonotaria citrea*	Intolerant
Kentucky warbler	*Oporornis formosus*	Intolerant
Louisiana waterthrush	*Seiurus motacilla*	Intolerant
Shrubland assemblage (early successional clearcuts)		
Indigo bunting	*Passerina cyanea*	Intolerant
Yellow-breasted chat	*Icteria virens*	Intolerant
Common yellow-throat	*Geothlypis trichas*	Intolerant
White-eyed vireo	*Vireo griseus*	Intolerant
Prairie warbler	*Dendroica discolor*	Intolerant
Field sparrow	*Spizella pusilla*	Intolerant
Gray catbird	*Dumetella carolinensis*	Tolerant
Forest-edge assemblage (fragmented landscapes)		
Brown-headed cowbird	*Molothrus ater*	Tolerant
Northern mockingbird	*Mimus polyglottos*	Tolerant
Chipping sparrow	*Spizella passerina*	Tolerant
American robin	*Turdus migratorius*	Tolerant
Eastern bluebird	*Sialia sialis*	Tolerant
Common grackle	*Quiscalus quiscula*	Tolerant
Eastern kingbird	*Tyrannus tyrannus*	Rural/agricultural
Red-headed woodpecker	*Melanerpes erythrocephalus*	Somewhat tolerant
Orchard oriole	*Icterus spurius*	Rural/agricultural
House finch	*Carpodacus mexicanus*	Tolerant

continued

Table 3.3—Some southeastern forest bird species and their sensitivities to urban and suburban development (continued)

Common name	Scientific name	Urban/suburban association
Habitat generalist assemblage		
Cardinal	*Cardinalis cardinalis*	Tolerant
Carolina wren	*Thryothorus ludovicianus*	Tolerant
Tufted titmouse	*Baeolophus bicolor*	Tolerant
Blue-gray gnatcatcher	*Polioptila caerulea*	Intolerant
Carolina chickadee	*Poecile carolinensis*	Tolerant
Blue jay	*Cyanocitta cristata*	Tolerant
Great crested flycatcher	*Myiarchus crinitus*	Somewhat tolerant
Summer tanager	*Piranga rubra*	Intolerant
Downy woodpecker	*Picoides pubescens*	Tolerant
Yellow-billed cuckoo	*Coccyzus americanus*	Intolerant
Eastern wood pewee	*Contopus virens*	Intolerant
Mourning dove	*Zenaida macroura*	Tolerant
Common crow	*Corvus brachyrhynchos*	Tolerant
Northern bobwhite	*Colinus virginianus*	Intolerant
Brown thrasher	*Toxostoma rufum*	Intolerant
Northern flicker	*Colaptes auratus*	Tolerant
American goldfinch	*Carduelis tristis*	Tolerant
Red-shouldered hawk	*Buteo lineatus*	Tolerant
Yellow-throated vireo	*Vireo flavifrons*	Intolerant
Ruby-throated hummingbird	*Archilochus colubris*	Tolerant
Eastern phoebe	*Sayornis phoebe*	Tolerant
Eastern screech-owl	*Otus asio*	Tolerant
Common nighthawk	*Chordeiles minor*	Tolerant
White-breasted nuthatch	*Sitta carolinensis*	Tolerant

Source: Canterbury and others 2000 [based on results from: Engels and Sexton (1994), Smith and Schaefer (1992), Dowd (1992), Beissinger and Osborne (1982), Rottenborn (1999), Linehan and others (1967), Blair (1996), Goldstein and others (1986), Friesen and others (1995), Long and Long (1992), Askins and Philbrick (1987), Aldrich and Coffin (1980), Bolen and Robinson (1995), Zimmerman (1991), and Hines and Anastasi (1973)].

other native birds including robins, yellow-billed cuckoos, and black-billed cuckoos. They can displace native eastern bluebirds, wrens, purple martins, and cliff swallows from their nesting sites (Arcieri 1992, Pimentel and others 1999). The deaths of adult and nestling bluebirds were documented in South Carolina resulting from aggressive competition with house sparrows (Gowaty 1984).

Effects of Urbanization on Forest Wildlife

Effects of urbanization on forest bird communities—A number of studies investigated changes to bird communities by comparing an urbanized site versus a less urbanized (or more forested) site. Many investigators found that urbanization decreased the species diversity of the avian community and increased avian density (or bird biomass), favoring dominance by a few species. Bird species vary in sensitivity to urbanization, leading to loss of sensitive species and a shift in the species composition of urban versus forest bird communities. Habitat specialists, including many forest insectivores, neotropical migrants, and forest interior species, have been documented to be less tolerant of urbanization. Beissinger and Osborne (1982), Smith and Schaefer (1992), Franklin and Wilkinson (1996), Kluza and others (2000), Croonquist and Brooks (1993), and Dowd (1992) all documented shifts in avian species composition with increasing urbanization.

Some investigators studied the response of bird communities across several sites or along a gradient of increasing urbanization. Gradient studies revealed a less clear pattern in bird species diversity and density peaks; in some cases the pattern shifted seasonally. However, shifts in the avian species composition were generally found as urbanization increased (Blair 1996, Clergeau and others 1998, Lancaster and Rees 1979, Rottenborn 1999).

Others investigated changes in the bird community at a single site through time as the area became urbanized or more forested. Butcher and others (1981), Askins and Philbrick (1987), Aldrich and Coffin (1980), Long and Long (1992), and Horn (1985) documented the loss of sensitive forest bird species after urbanization or their return after reforestation.

Table 3.3 lists selected forest bird species in the Southeastern United States and their tolerances to urban and suburban development.

Urban fragmentation and edge effects—Forest size and level of fragmentation and the effects on breeding birds—Increasing urbanization fragments forest habitat into smaller and more isolated tracts. Research on breeding forest birds has shown that some species have minimum area requirements. Many studies documented declines in the numbers of forest breeding migratory birds in small isolated forest patches (Danielson and others 1997). Fragmentation is considered to be a primary contributing factor to observed neotropical migrant declines.

Whitcomb and others (1981) found that many neotropical migrant species became increasingly rare as the size of the forest decreased. In addition, area sensitivities varied depending on the degree of isolation from larger forest tracts. They concluded that forest tracts needed to contain hundreds or perhaps thousands of acres to conserve populations of some forest bird species. Robbins and others (1989) suggested that when managing forests for wildlife, top priority should go toward providing for the needs of area-sensitive or rare bird species. When conservation of large contiguous forest tracts is not possible, they suggested that several moderately sized contiguous forests could be helpful in maintaining rare forest breeding birds.

Reduced reproductive success of forest nesting birds in small or fragmented forests may be due to increased nest predation or nest parasitism by brown-headed cowbirds. Nest parasitism is associated with brown-headed cowbirds, which lay their eggs in the nests of other species. These hosts then raise cowbirds at the expense of their own offspring. Nest predation can be caused by a combination of many avian, mammalian, and reptile species. Rates of nest predation have been found to be higher in small forest tracts than in large forest tracts, and small urban forest tracts experience higher rates of predation than comparably sized forest tracts in isolated rural areas (Wilcove 1985). Migratory songbird populations suffer the most serious effects from increased predation in small forest tracts. Keyser and others (1998), Donovan and others (1995), Robinson (1992), and Robinson and others (1995) all documented reduced reproductive success of neotropical migrants and other forest nesting bird species in fragmented forests due to higher rates of nest predation and/or nest parasitism.

Recently, investigators stress the importance of overall forest cover or landscape levels of fragmentation surrounding a local area when evaluating the presence or nesting success of area-sensitive or forest-interior birds. As indicated by Villard (1998), preference for forest-interior habitat or avoidance of small fragments tends to focus attention on the local scale, whereas processes underlying these phenomena may take place over landscape or even continental scales. Therefore, forest-interior preference and area sensitivity should be considered in a landscape context. In one study, forest cover in approximately 40-square-mile study plots was found to be the most important factor affecting the distribution of forest birds (Trzcinski and others 1999). Comparatively, the independent measures of forest fragmentation produced effects that were inconsistent and far less important than overall forest cover. In addition, the reduction in nesting success of forest birds due to nest predation and parasitism was much greater in heavily fragmented landscapes with low forest cover than in heavily forested landscapes (Hartley and Hunter 1998, Robinson and others 1995). Similarly, no differences were detected in the breeding success of worm-eating warblers in small and large forest tracts when high amounts of forest canopy cover were present in the surrounding landscape (Gale and others 1997).

In addition, landscape-level factors may partially affect the distribution of mammalian nest predators and, potentially, songbird nest-predation rates. A combination of local features, such as proximity to some types of edge, as well as broader landscape-level features, such as land use patterns, was determined to influence the abundance of these mammals (Dijak and Thompson 2000). At a broader scale, raccoons were more abundant in agricultural landscapes with high densities of streams than in forested landscapes with low densities of streams. Opossums were more abundant in heterogeneous landscapes with widely spaced patches of forest and high densities of riparian habitat.

A review of Breeding Bird Survey trends for the southern Piedmont physiographic area might lead one to conclude that perhaps urbanization is not a serious threat to sensitive forest breeding birds. As indicated in Hunter and others (2001a), very few vulnerable species in the southern Piedmont have declined overall from 1966 to 1996. This apparent stability, however, may reflect an overall increase in forest acreage and maturation of the forests during this period. As further summarized in Hunter and others (2001a), wood thrushes and red-eyed vireos have shown consistent declines within patches of mature forest in Piedmont suburban areas, such as Atlanta, GA. In addition, a number of area-sensitive woodland bird species, such as northern parulas, black-throated green warblers, Swainson's warblers, and worm-eating warblers, have population centers in relatively more forested areas, such as the southern Blue Ridge and the South Atlantic Coastal Plain, but are nearly absent as a breeding species over much of the southern Piedmont (Hunter and others 2001a). Perhaps more revealing than population trend data alone for woodland warblers and other sensitive mature forest species is the absolute abundances for those species as derived from the Breeding Bird Survey data (Hunter, W.C., May 2002. Unpublished analysis on Breeding Bird Survey data. 4 p. On file with: Kenneth L. Graham, U.S. Fish and Wildlife Service, Ecological Services, Suite 200, 1875 Century Blvd., Atlanta, GA 30345). Absolute abundances of these species in heavily fragmented physiographic areas, such as the southern Piedmont and the southern ridge and valley/southern Cumberland Plateau, are clearly much lower than those exhibited by more heavily forested, less fragmented physiographic areas, such as the southern Blue Ridge and northern Cumberland Plateau.

In the face of very low absolute abundances of sensitive woodland bird species, positive or negative population trends within heavily urbanizing areas, such as the southern Piedmont, may reflect habitat conditions and population trends in nearby physiographic areas that actually support those species' population centers and act as source populations. Ironically, some of the most forested physiographic areas in the Southeast have exhibited the steepest declines in forest birds in recent years. These areas have long been considered to be population sources for forest nesting birds (and still are, but to a more limited extent than previously thought) (Simons and others 2000). See chapter 4 for more information concerning population declines of forest birds in more forested physiographic regions and for trends in wood-warbler species in the Piedmont.

Connective corridors and offsetting the deleterious effects of fragmentation—The presence of connective corridors may help to reduce the isolation of wildlife populations in fragmented forests (MacClintock and others 1977, Machtans and others 1996, Wegner and Merriam 1979). Corridors may provide a connection that allows wildlife to move from one patch to another across an intervening, inhospitable landscape. This phenomenon has been especially well documented for disturbance-dependent grassland and scrub-shrub bird species, such as Bachman's sparrow, in largely forested areas (Dunning and others 1995). It is not obvious that animals possessing the mobility of birds need corridors to cross-fragmented landscapes, but it appears that the open space between forest islands is a barrier to movement of some songbirds (Whitcomb and others 1981). Gaps of 250 feet or more produced isolation characteristics for some songbirds in small forest fragments created by power lines and roads (Robbins and others 1989). Such gaps may not represent as serious a problem in largely forested landscapes, however (Gale and others 1997). Some investigators question the conservation value of corridors or question whether sufficient experimental evidence exists to draw conclusions on their benefits (Inglis and Underwood 1992, Simberloff and others 1992). Several potential negative effects and disadvantages of corridors should be considered prior to their use in overcoming fragmentation (Simberloff and others 1992). Disagreement over the value of corridors to overcome the effects of fragmentation for various species is likely to continue for some time. The use of corridors and the effect of fragmentation on movement patterns seem to be highly species-specific (Debinski and Holt 2000).

Fragmented forests have a greater proportion of edge habitats. Edges have generally been regarded by wildlife managers to have a positive effect on wildlife because the number of species increases near habitat edges (Yahner 1988). This positive effect likely remains true for birds in predominantly forested landscapes. In fragmented landscapes, however, maximizing species diversity is not always a desirable objective in light of the number of rare species that depend on large areas of habitat. Rates of nest predation and brood parasitism are greater at edges for some forest nesting birds (Gates and Gysel 1978), especially as overall forest cover becomes increasingly fragmented (Donovan and others 1997). Paton (1994) reviewed a number of studies that dealt with bird nesting success as a function of distance from an edge. Most studies found that nesting success decreased near edges as a result of increasing nest predation and parasitism rates. The strongest effects appeared to occur within about 125 feet of the edge. Indigo bunting nests along abrupt forest edges, such as agricultural edges, wildlife openings or campgrounds, had nearly twice the nest predation rate as those found along more gradual edges, such as those created by treefalls, streamsides, and gaps created by selective logging (Suarez and others 1997).

While the results of many investigations indicate that nesting success for forest birds is reduced by the proximity of edges, recent information indicates that such effects depend on the nature of the surrounding landscape. Hartley and Hunter (1998) reviewed various nest predation studies and concluded that nest predation rates decreased as the amount of overall forest cover increased. Edge effects were more apparent in largely deforested landscapes. Donovan and others (1997) found that nest predation rates were significantly higher near edges, but these increased rates were apparent only in highly and moderately fragmented landscapes and not in unfragmented landscapes. The ovenbird may be an exception, however. Even in an extensively forested landscape, slightly reduced rates of breeding success were documented for ovenbirds near forest edges (King and others 1996). Still, ovenbird reproductive success remains high overall, and other sensitive neotropical migrants fare better in highly forested landscapes (Gale and others 1997). Ovenbirds reproduce well in midsuccessional forests, and since such conditions are plentiful throughout eastern forests, the ovenbird is not considered a conservation priority species. See chapter 1 for more information about the effects of forest fragmentation on forest wildlife.

Not all investigators agree that higher nest predation rates occur in smaller forests or along forest edges (Friesen and others 1999, Haskell 1995, Matessi and Bogliani 1999, Yahner 1996, Yahner and Mahan 1996). Studies in large contiguous forest areas, such as the Great Smoky Mountains National Park, indicate that although these areas enjoy an overall higher nesting success rate for forest nesting birds (such as wood thrush), they may also support a more diverse and abundant predator community than more disturbed or less contiguous sites (Simons and others 2000). In addition, the magnitude and patterns of nest parasitism by brown-headed cowbirds is not consistent among studies (Coker and Capen 1995, Donovan and others 1997, Evans and Gates 1997, Gates and Gysel 1978, Hahn and Hatfield 1995, Robinson 1992, Robinson and others 1995).

Effects of urban environments on bird abundance and nesting success—In urban areas, forest-breeding birds may have lower abundances and lower nesting success. A 10-acre woodlot without any nearby houses had greater species richness and higher abundances of neotropical migrant species than did a 60-acre urbanized woodlot, indicating that the diversity and abundance of neotropical migrant birds decreased with increased urban development (Friesen and others 1995). Golden-cheeked warblers declined near urban development, apparently due to the increased presence of blue jays and greater nest predation (Engles and Sexton 1994). Declines of neotropical migrants were documented over a 50-year period in the North Carolina Highlands Plateau, likely due, in part, to the close proximity of residential development and urban fragmentation (Holt 2000). Nest predation rates were found to be greater for woodlands in the vicinity of human settlement (Matessi and Bogliani 1999). Mammalian nest predators were found to be more abundant in floodplain forests that adjoined residential and agricultural lands (Cubbedge and Nilon 1993).

Urban areas as habitat for birds—Urban woodlands are unsuitable habitat for many forest bird species, including many neotropical migrant birds, birds that require large habitat areas for breeding, birds that breed only in forest interior habitats, many scrub-shrub and grassland species, and those sensitive to urban disturbance. Urban and suburban preserves tend to be small and isolated from other forests. However, urban woodlands still provide habitat for some wildlife species and seasonally support migrating birds. Not all urban habitats are the same.

Woody vegetation volume is important in determining breeding bird diversity in urban settings (Goldstein and others 1986). Urban woodlots of 20 acres or more can support dense and diverse populations of breeding birds, provided that they have adequate shrub understory, mature and dead standing trees, and vegetative edge types of sufficient width and proper quality (Linehan and others 1967). Large urban parks with well-preserved natural forest habitat support bird populations more characteristic of native forests (Gavareski 1976). Urban parks, cemeteries, schoolyards, and other open spaces are prime sites for wildlife management (Bolen and Robinson 1995). For example, Washington, DC, has only house sparrows, pigeons (rock doves), and starlings in the downtown area, but nearby in the spring gardens surrounding the White House, 19 species are present.

In urban environments, the objective of wildlife management should be to maintain biological diversity by retaining sufficient habitat for the maximum number of wildlife species (Milligan and others 1995). Urban wildlife habitat designs must consider the size, composition, connectivity, dynamics of the habitat patches, and human perceptions of the habitat areas. At the same time, however, urban wildlife habitats must be at a scale compatible with the surrounding urban uses. Constraints are necessary to promote human health and safety, and to meet habitat requirements of the different wildlife species.

Urban habitats pose additional risks to resident avifauna. An estimated 98 million birds are killed each year in the United States from window collisions with high-rise buildings (Bolen and Robinson 1995). In addition, an estimated 2 to 4 million birds are killed each year in the Eastern United States due to collisions with communication towers (Weisensel 2000). The relative contributions of these mortality sources to the declines of any conservation priority bird species were not described in these references.

Effects of urbanization on birds of prey and scavengers—Birds of prey, such as hawks, eagles, and owls, can be vulnerable to the effects of urbanization because they are at the tops of food chains, and their home ranges are larger than those of most other birds (Adams 1994). Hawk species differ in their requirements for nesting habitat and tolerance for forest openings and human disturbance. Cooper's hawks abandon nest sites when housing construction and residential disturbance encroach on established nest sites (Bosakowski and others 1993). There is evidence, however, of adaptability of various hawk species to urban settings. Broad-winged hawks are more tolerant of forest openings when selecting nest sites than red-shouldered, red-tailed, or Cooper's hawks (Titus and Mosher 1981). Red-shouldered hawks in New York and New Jersey have higher nest productivity with increasing distance from human habitation (Speiser and Bosakowski 1995).

Bald eagles generally select well forested areas near water bodies and avoid areas of human development and areas of high boat and pedestrian traffic (Buehler and others 1991a, 1991b; Chandler and others 1995). On the lower Melton Hill Reservoir and the adjoining Clinch River in eastern Tennessee, residential and industrial development was found to be the primary factor limiting habitat suitability for eagle nesting (Buehler 1995).

When not searching for food, black and turkey vultures tend to prefer forested habitats free of buildings for roosting and nest sites (Coleman and Fraser 1989). Nests are frequently located away from human disturbance in rock crevices and in roadless, forested, and undeveloped areas. Nesting success for vultures was found to increase farther from buildings due to lower disturbance and less depredation by dogs.

Although some raptors are sensitive to urban disturbance, there may be differences among individuals, species, and regions of the country. Raptors that are tolerant of urban environments include Mississippi kites, sharp-shinned hawks, Cooper's hawks, red-shouldered hawks, and red-tailed hawks (Adams 1994). Urban woodlands, even those composed primarily of exotic vegetation, lawns, and urban development, are acceptable to some red-shouldered hawks (Bloom and others 1993). One pair of red-shouldered hawks successfully fledged young within 65 feet of people engaged in jogging, picnics, and baseball games. American kestrels also have adapted to urban environments where suitable nesting cavities are available (Adams 1994).

The screech owl thrives in some suburban environments, especially those with large wooded lots (Gehlbach 1986). Burrowing owls, barn owls, and, occasionally, great horned owls have also been found in metropolitan environments (Adams 1994). Burrowing owls benefit from light levels of urban development and reach their highest densities in areas 55 to 65 percent developed. Other population-limiting factors are encountered beyond that development level, however.

Effects of urbanization on mammals—In general, urban environments support fewer species of mammals than surrounding rural areas (Adams 1994). The species that occur in urbanized environments tend to be habitat generalists rather than specialists. Urbanized areas can support high populations of exotic species, such as the house mouse and Norway rat. In less urbanized areas where large green spaces remain, more species are likely to be encountered. Downtown Boston cemeteries support 20 species of resident mammals (Bolen and Robinson 1995).

Small and medium-sized mammals, especially granivores, are the most abundant mammals found in urban and suburban environments (Adams 1994). In one study, mammals found in urban greenspaces were primarily habitat generalists that utilize a mosaic of habitat types (VanDruff and Rowse 1986). Deer mice, meadow voles, tree squirrels, ground squirrels, chipmunks, and woodchucks are common residents of urban areas (Adams 1994). Some small mammals, however, are habitat specialists that do not easily adjust to changes brought about by urbanization. Fragmentation of habitat in the Great Dismal Swamp of Virginia and North Carolina by residential subdivisions and industrial parks may be contributing to the decline of five indigenous subspecies of mammals (Rose 1991). The Allegheny woodrat is restricted to only a few habitats and is listed as threatened in Pennsylvania because of statewide declines (Balcom and Yahner 1996). Increases in residential and agricultural development were observed near sites of extirpation. The few sites still occupied by the woodrat generally had less fragmented surroundings (agricultural lands) than sites of extirpation.

Large herbivores do not easily find suitable habitat in highly urbanized settings (Adams 1994). Their large body sizes and correspondingly large home ranges exclude them from many urban environments. Nevertheless, many cities in North America have very high densities of white-tailed deer. Problems with damage to urban vegetation in sensitive areas, such as flower gardens and parks coupled with high instances of deer-vehicle accidents, have prompted some cities to initiate population control activities (Bolen and Robinson 1995).

Small insectivorous mammals, such as shrews, moles, and bats, are commonly encountered in most residential areas. Suburban residential areas often make excellent habitat for medium-sized omnivores, such as raccoons (Hoffmann and Gottschang 1997), opossums, armadillos, and skunks (Adams 1994).

Red foxes are more tolerant of urban areas than gray foxes. They occasionally den in large wooded areas within some larger cities. Urban foxes are common in many British cities, even in the districts most densely populated by humans (MacDonald and Newdick 1982). In a Boston cemetery, resident red foxes hunt a burgeoning gray squirrel population (Bolen and Robinson 1995). Gray foxes are more wary of urbanized areas, but can be found in rural residential areas (Harrison 1997). The threshold for avoidance of residential areas by gray foxes is between 130 and 325 residences per square mile. Coyotes are becoming more common in urban and suburban settings (Adams 1994). Coyotes occur in suburban Seattle and Los Angeles, in residential areas north of New York City, and in Lincoln, NE. In Lincoln, one coyote spent more than 70 percent of his time in a 35-acre residential subdivision (Bolen and Robinson 1995).

Large predators, such as wolves, cougars, and bears, are not part of urban mammal communities (Adams 1994). They have been eradicated from most rural areas as well. Black bear distribution in coastal North Carolina is negatively correlated with human density and positively correlated with percent of total forested land (Jones and others 1998).

Effects of urbanization on reptiles and amphibians—Some amphibians and reptiles have characteristics that make them vulnerable to the effects of urbanization (Adams 1994). They are less mobile than birds or mammals, and dispersal rates are slower. With habitat fragmentation, many amphibians and reptiles exist in localized distributions rather than one continuous population. Urbanization tends to exclude specialized reptiles and amphibians, while species with broad ecological tolerances and more general habitat needs tend to be more successful. Many reptiles and amphibians are eliminated when wetlands and aquatic habitats are lost due to drainage, channelization, or filling. Removal of ground cover and underbrush eliminates habitat for many salamanders and snakes (Adams 1994).

Amphibians are especially susceptible to local extirpations and constraints on recolonization due to the short distances traveled, site fidelity, and physiological constraints (Blaustein and others 1994). The effects of forest habitat loss during urbanization may be especially severe for forest-dwelling salamanders. Schlauch (1976) found that woodland salamanders, such as the blue-spotted, spotted, marbled, and eastern tiger salamander, were reduced in distribution in urbanized areas of Long Island. Loss of ponds, lowered water tables, urban pollution, reduced amounts of woodlands, and collections for pets were contributing factors. In addition, the northern two-lined salamander disappeared from most areas on Long Island due to destruction of suitable springs. This species needs cool and flowing spring water to breed. In western North Carolina, the abundance and diversity of salamanders were drastically reduced following clearcutting of the forests (Ash 1997, Petranka and others 1993). There is substantial debate about the recovery and long-term stability of salamander communities in managed forests (Ash 1999, Petranka 1999), but deforestation associated with urban development would be permanent, with little likelihood of recovery for many salamander species.

Recolonization of suitable areas can also be problematic for some reptiles, especially those that are habitat specialists. The Florida scrub lizard is a rare endemic, and its largest remaining population is in Florida sand pine scrub on the Ocala National Forest (Tiebout and Anderson 1997). The lizard has limited vagility and can only occupy young seral stages of a regenerating forest (less than 7 to 9 years of age). Scrub lizards probably do not disperse through forests older than about 12 years of age. Fire suppression and the lack of forest successional dynamics have contributed to the rarity of this lizard.

The threatened gopher tortoise also is sensitive to urbanization. Egg and hatchling mortality can be quite high in urban areas (see sections "Effects of exotic animals on forest wildlife: exotic insect pests and forest wildlife" and "Effects of exotic animals on forest wildlife: effects of exotic wildlife on native forest wildlife"). This problem is compounded by low reproductive rates (Adams 1994). The gopher tortoise has been extirpated from urban areas in Mobile County, AL (Nelson and others 1992). Populations are more stable, however, in areas with less severe habitat disturbance. Habitat modifications and land use changes associated with urbanization and agricultural development have eliminated the timber rattlesnake from much of its historic range in east Texas (Rudolf and Burgdorf 1997).

Although urbanization excludes some sensitive forest reptiles and amphibians, urban environments may provide habitat for some species. The heavily urbanized western end of Long Island still supported 28 of the 37 species documented to historically exist on Long Island (Schlauch 1976). The less developed, eastern end supported 35 of the 37 species. Herpetofauna found to be urban tolerant by Schlauch (1976) included the red back salamander, Fowler's toad, the brown snake, the garter snake, and the eastern box turtle. Due to pet collection, box turtles disappeared quickly from areas near any ground-level nature trails, however.

Other general effects of urbanization on forest wildlife—Many habitats, such as the longleaf pine ecosystem or pine-oak woodlands of the Southern Appalachians, are dependent upon fire for maintenance. Fire suppression has affected the quality of wildlife habitats in some southern forests. In many forest areas, management now includes prescribed burning. However, the increasing presence of roads and residential areas has interfered with the use of prescribed fire. For more information on the effects of fire suppression and prescribed burning, see chapters 4 and 25.

For more information about the effects of air pollution on forest health, see chapter 18. For more information about the effects of increasing demand for timber products on southern forests, see chapter 13.

Effects of Agricultural Land Use on Forest Wildlife

Forest wildlife densities and movement along the forest/ agricultural edge—Forest wildlife species differ in their responses to forest/agricultural edges. Some wildlife species are limited to forest interior habitats and avoid edges. Other wildlife species are adapted to edges and forest openings, or may be attracted to special habitats created at forest/agricultural interfaces. Small mammal species exhibited differing responses at forest/field edges (or forest wildlife openings) (Manson and others 1999, Menzel and others 1999, Wegner and Merriam 1979). Increased numbers of mammalian nest predators were found along forest-field edges (Gates and Gysel 1978), higher densities of mammalian predators were found in floodplain forests adjoining residential and agricultural land (Cubbedge and Nilon 1993), and raccoons were found to be more abundant in forest edges adjacent to agricultural fields and streams (Dijak and Thompson 2000). In contrast, Heske (1995) found no differences in the abundance of furbearing and small mammals along forest/farm edges versus forest interiors in southern Illinois.

Nest predation of forest nesting birds adjacent to agricultural areas— For information about the effects of small forest fragments and forest edges on the success of forest-nesting birds see section "Effects of urbanization on forest birds: urban fragmentation and edge effects."

Some avian species in forests near agricultural areas have reduced nest success rates. Rates of nest predation for songbirds were found to be ubiquitously high in a study site bordering agricultural fields. Mammalian predators (especially raccoons) were abundant throughout the study site and present on all transects surveyed (Heske and others 1999). Similarly, higher predation rates for ground nests were documented in forests fragmented by agricultural land due to more abundant avian predators (Huhta and others 1996) and in an area fragmented by agriculture, greater abundances and species richness of nest predators (particularly avian nest predators and snakes), as well as more abundant cowbirds, were found along pasture-forest edges (Chalfoun and others 2002). Increased numbers of nest predators (crows and blue jays) were noted during bird surveys in the Great Smoky Mountain National Park (Wilcove 1988). Apparently, agricultural and other land conversions outside the park boundaries caused an increase of these nest predators, even in this large, relatively contiguous forest area.

Agricultural areas as habitat for forest wildlife—

■ *Early successional species:* Many bird species dependent on open habitats, such as grasslands, prairies, savannas, glades and barrens, are now in serious decline in the Eastern United States (Hunter and others 2001a). Today, many of these early successional and disturbance-dependent species are found associated with active and abandoned farmland, pastures, and other human forest clearings. Prior to European settlement, these species were found in naturally occurring and Native-American-maintained forest openings. Many of these disturbance-maintained ecosystems have been lost from the landscape during the last 300 years. Some species dependent on them found suitable nesting habitat in human-created fields following loss of the natural openings. Populations of disturbance-dependent birds and other wildlife vary along with trends in agriculture. Conversions of pastures to more intensively cultivated row crops or intensively mowed, fescue-dominated pastures, the maturing of abandoned farm fields in some areas of the South, and the trend to larger fields of cash crops with accompanying loss of fence-row habitat have all affected early successional species. Information from the 1997 National Resource Inventory indicates that the 13 Southern States lost about 2.2 million acres of pasture between 1992 and 1997, a net loss of about 3.4 percent (USDA Natural Resources Conservation 2000). These species are in trouble not only because of the intensification of farming and declining numbers of pastures, hay meadows, and abandoned fields, but also due to suppression of natural disturbances—fires, beaver activity, and floods—that generate natural grass-lands and shrublands (Askins 2001).

The introduction of exotic, cool-season pasture grasses was probably in response to overgrazing of native warm-season species and deteriorating range conditions (Twedt and others, in press). Use of "improved" cultivars, such as tall fescue, red fescue, Bermuda grass, weeping love grass, and many others, began in the mid-1930s. Exotic grasses, such as tall fescue, can be grazed quite close to the ground and can be hayed during the mid-nesting season of many grassland bird species. Depending on their management, intensively grazed or frequently mowed fescue pastures offer little or no cover for wildlife and can be poor habitat for northern bobwhite (Barnes and others 1995) and other grassland species.

Eastern cottontail populations were found to remain highest in areas with relatively high amounts of pasture, stable woodlands, hayfields, and fields planted in small grains, such as wheat, oats and barley (Mankin and Warner 1999). The presence of pasture seemed to be the most important factor, however. In contrast, increases in row crops, such as corn and soybeans, were accompanied by declines in cottontails. Pasture environments apparently maintained cottontail abundance because they are closest to their preferred vegetation structure (old fields and early successional shrub lands). Similarly, landscape features, such as percentage of woodland on farms, percentage of farmland in nonrow crops, percentage of land in soil-protecting crops, and percentage of land in conservation tillage, were used to calculate habitat indices (Ribic and others 1998). These indices are important in determining areas likely to support high populations of northern bobwhites and cottontails. Indices indicating farming disturbance, such as percentage of land under grazing and percentage of land on which fertilizers, pesticides, and herbicides were applied, were associated with lower populations.

■ *Importance of vegetated fencerows, hedgerows, and wooded corridors:* The presence of woody fencerows in agricultural areas provides important habitat for many wildlife species (Bolen and Robinson 1995). In areas where agriculture constitutes a majority of the land use, fencerows with a continuous row of trees and shrubs can provide habitat for up to 36 species of birds per 6.2-mile segment, whereas fencerows without woody vegetation support 9 or fewer species over the same distance. Forest edges bordered by multiflora rose hedgerows had higher bird species diversity than open forest edges, but habitat generalists and forest-edge species provided most of the increased bird diversity (Morgan and Gates 1982). Forest edges with hedgerows had more cover in the first 6 feet aboveground level than open forest edges and retained more of this cover during the winter. In addition, cottontails were also more frequent in forest edges where hedgerows were present compared to open forest edges (Morgan and Gates 1983). Similarly, farmstead shelterbelts were documented to be valuable habitat for small mammals in agricultural areas (Yahner 1983).

Vegetated fencerows may be important for the movement of some wildlife species, allowing them to reach isolated forest patches across a matrix of open agricultural fields. Chipmunks and white-footed mice tend to move between wooded habitats down vegetated fencerows rather than crossing open fields (Wegner and Merriam 1979). Similarly, many forest-nesting bird species move from one wooded habitat to the next along vegetated fencerows rather than flying directly across open fields. Even when woodland birds, such as eastern pewee, red-eyed vireo, and wood warblers, foraged in open fields, they first moved from the woods down fencerows, then from fencerows into the open fields. MacClintock and others (1977) documented that a narrow, disturbed corridor of grazed woods and early second-growth forest could reduce the isolation of a forest patch, allowing it to maintain a high diversity of forest-nesting birds.

Fencerows in agricultural areas may have negative effects on some species, however. Nest survival for loggerhead shrikes in fencerows was documented to be lower than for those nesting in the adjoining pastures due to higher nest predation (Yosef 1994). Most of the potential nest predators observed during the study either flew or walked along fencelines, and appeared to avoid crossing open pastures. Similarly, area-sensitive grassland bird species avoided nesting in grassy pastures within the first 165 feet of wooded fencerows (O'Leary and Nyberg 2000). Sensitive grassland nesters included two conservation priority species—Henslow's sparrow and bobolink.

■ *Foraging habitat for forest wildlife*: Agricultural areas, including grain fields, pastures, fruit orchards, gardens, and vineyards, are important forage areas for many wildlife species (Martin and others 1951). Not all forage use of agricultural land by wildlife results in damage to crops. Foraging by insectivorous birds and mammals and consumption of weed seeds by wildlife is beneficial to agriculture. Wildlife often consume waste grain left behind by mechanical harvesting machines or consume fruit that has fallen on the ground. In other cases, however, loss and damage to crops by wildlife have been clearly documented. Martin and others (1951) documented the value of several agricultural commodities for wildlife. Corn is consumed by over 100 species of wildlife, including 17 species of upland gamebirds, 59 species of songbirds, 10 species of fur and game mammals, 6 species of small mammals, and 3 species of hoofed browsers. Wheat is consumed by more than 94 species of wildlife, and oats are consumed by at least 91 different species. Rice and apples are other important agricultural commodities eaten by foraging wildlife in the South.

Fallow fields were the most common habitat selected by bobwhite, even though crop fields, wildlife management plots planted annually in small grain, and woods managed by prescribed burning, were available nearby (Yates and others 1995). Apparently, insects were the most important food resource for feeding bobwhite hatchlings. Insect sampling revealed that fallow fields had more insects than other available habitats.

Black bears in the Southeast feed more in agricultural areas than in other parts of the United States, but their use of these areas may increase their vulnerability to hunting, lowering the overall rates of survival, especially for males (Hellgren and Vaughn 1994). In coastal North Carolina, corn crop damage by black bears amounted to about 0.6 percent of the total area surveyed (Maddrey and Pelton 1995). Most of the damage was within 165 feet of the forest edge. In questionnaires completed by coastal North Carolina farmers, deer were the major cause of crop depredation (Maddrey and Pelton 1995). Crop damage by black bears, birds, and raccoons was reported less frequently.

Raccoons frequently use agricultural areas for foraging. One study found that raccoons in an agricultural area foraged mainly on corn, which accounted for up to 76.2 percent of their diet (Sonenshine and Winslow 1972). Coyotes were found to be well adapted to agricultural areas in Vermont (Person and Hirth 1991). They preferred hardwood forests in the winter and spring, and farmland during the summer and fall.

Great horned owls are habitat generalists that prefer open cropland and pastures for foraging (Morrell and Yahner 1994). Barn owls also prefer to forage in pastures and grass-dominated agricultural areas (Bolen and Robinson 1995).

Wintering flocks of grackels, red-winged blackbirds, starlings, and brown-headed cowbirds use fields and feedlots for foraging. One such wintering flock removed 1,300 to 7,000 tons of corn each winter from a total foraging range of about 541,000 acres (White and others 1985). In a control measure, over 1 million birds were killed with the surfactant PA-14 one winter. Recruitment of birds from surrounding areas caused the roost to return to prekill levels within about 2 weeks. Roost fidelity for such wintering flocks averages only 3.5 to 4.4 nights per individual. Thus, the daily population turnover rate for the roost is about 23 percent.

■ *Hazards of agriculture to wildlife*: Although agricultural areas are habitat for many wildlife species, they can also subject them to hazards not encountered in natural areas. Mowing equipment and nighttime mowing has increased the mortality of eastern cottontails, bobwhite, and other wildlife attracted to pastures and hayfields (Bolen and Robinson 1995).

Many wildlife species forage in agricultural fields, but crop losses have resulted in lethal and nonlethal depredation control measures (Bolen and Robinson 1995). Under some conditions, certain crops may be harmful to wildlife. Geese that consume dry soybeans may harm or obstruct their esophagi as the swelling soybeans cause hemorrhaging and necrosis, or prevent the passage of food to the stomach. Aspergillosis is a fungal infection of the respiratory tract, contracted by birds exposed to molding crops. Once contracted, the infection can be spread to other birds, causing sizable die-offs.

Wildlife living and foraging in agricultural areas are exposed to insecticides, herbicides, and fertilizers

(Bolen and Robinson 1995). Many insecticides are not species-specific and can be lethal to wildlife through direct exposure or through ingestion of contaminated prey species. Some of the more toxic pesticides, including the chlorinated hydrocarbons DDT, Aldrin, and others, are now banned in the United States, but because of long residual times and heavy pesticide buildups, it has taken some time for their deleterious effects to fade. Most herbicides approved for use today are not directly toxic to forest wildlife if applied correctly. Indiscriminant use can indirectly harm wildlife, however, by reducing important vegetation for cover and forage. Fertilizers in granular form can resemble seeds or grit and offer a potential hazard to birds that might ingest a large number of granules.

Old field successional areas—Some areas of the South are likely to experience a reduction in agricultural land uses with a subsequent return to forest habitat (see chapter 6 for more information). Many of these increases in forest acres will undoubtedly be in the form of pine plantations rather than natural forest types, however (see chapter 13). See chapter 4 for a discussion of the influence of pine plantations on forest wildlife and habitats.

Abandoned agricultural land undergoes a series of vegetation changes that provide important habitat for a number of wildlife species. The return to old-field habitat benefits many disturbance-dependent bird species. Successful management for many of these rare and declining birds will require adequate space for area-sensitive species, connecting corridors between early successional habitat areas, and availability of areas in specific vegetation stages to offset natural plant succession (Hunter and others 2001a). Breeding bird density and species composition shift as abandoned farm fields undergo natural vegetative succession to mature forests (Johnston and Odum 1956). A few species, such as the cardinal, persist through many plant successive stages; but most birds appear to have a definite range of vegetative stages. Browsing mammals, such as deer, also benefit as abandoned agricultural areas undergo the vegetative transition into scrub-shrub habitats (Adams 1994).

Old-field habitats can vary in vegetative structure. The presence of exotic vegetation in agricultural environments is an influence that persists long after fields are abandoned. Previous types of agricultural use can influence the vegetative structure and, hence, the wildlife habitat in a particular abandoned field. Abandoned pastures differed markedly in their vegetation compared to previously cultivated old fields (Stover and Marks 1998). Exotic herbaceous plants in an old-field environment reached their peak abundance within 65 feet of the forest edge (Meiners and Pickett 1999).

Restored bottomland hardwood forests failed to regain their wildlife habitat value relative to mature forests even 50 years after agricultural usage (Shear and others 1996). Although the regenerating forests had similar structural attributes to the uncut forests, the lack of heavy seeded, mast-producing tree species (oaks and hickories) made them generally less useful for mast-dependent forest wildlife. Conversely, bottomland hardwood reforestation efforts that rely solely on oak planting are slow to produce a substantial three-dimensional forest that provides useful habitat for nongame species, including many neotropical migrants (Twedt and Portwood 1997). More naturally invading species became established in bottomland hardwood restoration areas sown with acorns than in areas planted with oak seedlings (Twedt and Wilson, in press).

Other general effects of agriculture on forest wildlife—Agricultural land uses have resulted in fire suppression and interruption of presettlement forest fire patterns. Lack of fire in most forest habitats has greatly affected the quality of wildlife habitat. For more information on the effects of fire suppression and prescribed burning, see chapters 4 and 25.

Agricultural disturbance has permitted introduction of a great many exotic plant and animal species. See section "Effects of exotic species on forest wildlife and wildlife habitat" of this chapter for information about the impacts of exotic plant and animal species on forest wildlife.

Effects of Linear Land Uses (Roads, Power Lines, and Trails) on Forest Wildlife

Habitat displacement of wildlife by roads and power lines—Some forest wildlife are excluded from or are less numerous in areas adjacent to roads and highways. Woodland breeding birds and terrestrial birds were found to have reduced densities adjacent to highways (Reijnen and others 1995, Kuitunen and others 1998). Some species clearly avoided the road, while others appeared to favor road-forest edges. Birds responding to corridor/forest edges along a power line corridor could be divided into edge, deep forest, and unaffected species (Kroodsma 1982).

Road and power line corridors may vary in their effects on forest wildlife, depending on corridor width. Forest-interior, neotropical migrant birds exhibited diminished abundances along wide power line corridors (50 to 75 feet) but not along narrow forest openings (of 25 feet) along unpaved dirt roads (Rich and others 1994). Such edge effects may not be as important for birds nesting in predominantly forested landscapes. In a landscape more than 70 percent forested, worm-eating warblers in small forest patches, separated by paved two-lane roads and house lots, were found to have nesting success comparable to those nesting in large forest tracts (Gale and others 1997). However, even in heavily forested landscapes, ovenbirds showed reduced densities of breeding territories and reduced pairing success within 500 feet of forest roads (Ortega and Capen 1999). Therefore, while edges of narrow corridors may be acceptable habitat for some bird species, they may be unsuitable for others. These issues must be evaluated in terms of the conservation concerns for the species at issue in a given situation (see chapter 4 and section "Effects of urbanization on forest birds: urban fragmentation and edge effects" of this chapter for discussions concerning ovenbird response to edges versus conservation status).

Forest roads were found to reduce the abundance and species richness of macroinvertebrate soil fauna (Haskell 2000). This effect extended up to 330 feet into the forest. Although wider roads and those with a more open canopy produced steeper declines, even narrow roads through forests produced marked edge effects.

Early successional and forest edge habitat—Some wildlife are attracted to roadsides and power line rights-of-way because of grassland, early-successional, or edge habitat. The value of roadsides and utility corridors has been documented for grassland and habitat generalist species of small mammals (Adams and Geis 1983, Johnson and others 1979).

Corridor width and vegetative characteristics influence the attractiveness of the habitat for bird species. Road rights-of-way are important habitat for birds that nest in edges and ecotones (Warner 1992). The number of roadside nests and species increased with roadside width. Mowing schedules, diversity of vegetation, and vegetative structural complexity affected the habitat value of roadsides for nesting birds. Narrow power line corridors (40 feet wide) had a reduced diversity of birds compared to wider corridors (100 feet or more) (Anderson and others 1977). Wide corridors attracted more grassland bird species. Power line corridors with increased patchiness of shrub vegetation, showed increased fledging success of nesting birds (Chasco and Gates 1992). Fledging success decreased, however, as the habitat became more homogeneous. Many early successional and disturbance-dependent bird species can be found in roadsides and utility rights-of-way (Hunter and others 2001a, Meehan and Hass 1997), but corridors lacking shrub growth may have fewer nesting and wintering birds (Meehan and Hass 1997). Corridor nesting birds were more dense in the corridor interiors than along the edge (Kroodsma 1987).

Linear corridors as dispersal barriers for wildlife—Small forest mammals, such as eastern chipmunks, gray squirrels, and white-footed mice, were found reluctant to venture onto road surfaces when the distance between cleared road margins exceeded 65 feet (Oxley and others 1974). Four-lane highways acted as effective barriers against the movements of these small forest mammals. Medium-sized mammals, such as woodchucks, porcupines, raccoons, and striped skunks, crossed wider cleared road margins more often, but suffered higher road mortality than small mammals. Similarly, the movements of white-footed mice across roads, including narrow gravel roads, were found to be infrequent (Merriam and others 1989); and paved roads were found to be a significant barrier to the movements of woodland mice (Mader 1984). Even small forest roads not open to public traffic were seldom crossed.

The presence of roads appeared to substantially hinder the movements of forest amphibians (Gibbs 1998). In a different study, primary and secondary roads did not affect the presence and movement of forest frogs and toads (DeMaynadier and Hunter 2000). The movement of forest salamanders was significantly inhibited by primary forest roads, but the minor forest roads had little effect.

Black bears in the Pisgah National Forest of North Carolina almost never crossed an interstate highway; roads with low traffic volume were crossed more frequently than those with high traffic volume (Brody and Pelton 1989). Bears also appeared to adjust their home ranges to areas with lower road densities.

The nature of the corridor edge may determine how strongly that edge serves as a boundary for wildlife. Abrupt vegetative transition from forest to mowed grass on the edge of a power line corridor was found to be a barrier to forest birds and served as a natural territorial boundary for many bird species (Chasco and Gates 1992). When the vegetative contrast of the corridor was softened by shrubby vegetation, however, there was greater overlap between mixed-habitat and forest bird species. Power line corridors with abrupt edges were also avoided by small and medium-sized mammals because of difficulties in crossing the dense grass mats (Gates 1991). Corridors with a wide shrub zone along the edge had increased use and permeability to movement.

Wildlife underpasses can be an effective way to relieve the barrier effect of roads for some wildlife species (Clevenger and Waltho 2000). Wildlife differ in their abilities to utilize underpasses. In south Florida, white-tailed deer, raccoons, bobcats, the endangered Florida panther, alligators, and black bears were all documented to use underpasses to traverse an interstate highway (Foster and Humphrey 1995). Considerations for topography, habitat quality, location, and the level of human activity in the vicinity are important in designing a successful wildlife underpass (Clevenger and Waltho 2000).

Linear corridors as dispersal routes for wildlife—Road rights-of-way also can facilitate the movement of wildlife. Some grassland and early-successional species, such as Bachman's sparrow, require grassy and shrub-dominated corridors to facilitate their movement to and from isolated patches of suitable habitat (Dunning and others 1995). Meadow voles greatly expanded their range in central Illinois after the establishment of continuous strips of dense, grassy vegetation along interstate highways (Getz and others 1978). In contrast, the prairie vole is not restricted in movement by interruptions in grassy habitats. This species remains dominant in grassy sites not connected to the interstate, such as pastures and county roadsides. Similarly, a shrubby power line corridor and edges served as travel lanes for red foxes and striped skunks in a fragmented landscape (Gates 1991); but mammalian nest predator abundance was found to be influenced by both local and landscape-level features (Dijak and Thompson 2000).

Black bears use roads in the Great Dismal Swamp National Wildlife Refuge as travel corridors through the dense pocosin vegetation (Hellgren and others 1991). Such road use by bears is more characteristic among "unharvested" or protected populations. Hunted bear populations generally avoid roads, especially those with unrestricted use by humans.

Wooded roadside corridors serve as travel lanes for native forest mammals, but use of corridors taper off with distance from the forest (Downes and others 1997a and 1997b). Wooded road corridors appear to be used heavily by nonnative house mice and black rats, reducing their value as a remedy for habitat fragmentation. Males of some mammal species may utilize corridor habitats in greater numbers than females, indicating that roadside forest corridors may function as intraspecific filters.

Road mortalities and forest wildlife—Mortality along roads and highways has been well documented for many species of wildlife, but a number of factors influence the severity, including season, weather events, type of road, location of road, and road density. During a 14-month period along a dual-lane highway, road mortalities were documented for 11 species of mammals, 12 species of birds, 5 species of reptiles, 9 species of amphibians, and insects belonging to 11 orders (and more than 249 different species) (Seibert and Conover 1991). Amphibian mortalities were higher in certain seasons and after rains. Populations of timber rattlesnakes were reduced in areas of eastern Texas having high road densities (Rudolph and Burgdorf 1997). Road-related mortality was a significant threat to raptors, especially northern saw-whet owls and eastern screech owls (Loos and Kerlinger 1993); but road kill numbers varied with season, location, road type, and species involved.

Mortality rates of small forest mammals, such as Eastern chipmunks, gray squirrels, and white-footed mice, were highest when cleared road margins were about 45 to 115 feet (Oxley and others 1974). Mortality rates for these small mammals dropped as cleared margins grew wider, mainly because they seldom attempted crossings of wider forest clearings. Mortality of medium-sized mammals, such as woodchucks, porcupines, raccoons, and striped skunks, increased with increased cleared width, reaching a peak when traffic density was high and young were emerging. Small mammal road mortalities on interstate highways was found to be greatest for species with highest densities in the right-of-way habitat, but the loss did not appear to be detrimental to populations of these species (Adams and Geis 1983). Road mortalities for white-tailed deer along interstate highways have been documented by Reilly and Green (1974) and Puglisi and others (1974). Road mortality of vertebrates were recorded in north Florida (Cristoffer 1991). Mortality increased with increasing speed limits and increasing density of roadside vegetative cover.

Population impacts of road-induced mortality can be significant for some wildlife species. In south Florida, road kills are the largest source of human-induced mortality for the endangered Florida panther and the endangered Key deer (U.S. Fish and Wildlife Service 1999).

Spread of exotic plants and animals—Roads and power line corridors provide habitat and mechanisms for the spread of some exotic plants and animals. All high- and low-use roads sampled in an experimental forest contained at least one exotic plant species, some had as many as 14 (Parendes and Jones 2000). Even abandoned spur roads with no traffic over the last 20 to 40 years still had numerous exotic plants. Narrow, linear forest openings associated with roads and power lines appear conducive to establishment of the red imported fire ant (Stiles and Jones 1998). See the review in Trombulak and Frissell (2000) and the information compiled by the National Resources Defense Council (2000) for more information about the spread of exotic plants and animals along roads.

Other effects to wildlife from roads and power lines—Roads can provide hunters and poachers with increased access into forested areas (Natural Resources Defense Council 2000). Many large mammals are exposed to increased hunting pressure near roads, and some may have difficulties maintaining their populations near roadsides. In the Appalachian Highlands, management of black bears requires a special concern for road density (Clark and Pelton 1999). While overall black bear populations in the Southern Appalachians are considered stable to increasing at the present time, most black bear mortality is human-induced and includes hunting, poaching, and road kills. Hunting and poaching efficiencies increase along with improved vehicle access, and black bear habitat suitability is increased when the density of roads is kept low or if logging roads are closed after the timber has been harvested (Clark and Pelton 1999). Similarly, Brody and Pelton (1989) concluded that the primary effect of roads in bear habitat in western North Carolina was an increase in the vulnerability of bears to hunting.

Roads can subject wildlife to increased levels of heavy metals, salts, and organic compounds through accumulation in plants, soil, and water (see the review in Trombulak and Frissell 2000). Corridor maintenance by mowing presents a hazard for some ground-nesting birds and other wildlife species (Bolen and Robinson 1995).

For a discussion of indirect effects of roads, including promotion of further human land use changes, see the review in Trombulak and Frissell (2000).

Effects of trails on forest wildlife—The effects of trails appear to be better documented for plants than other taxa. Trampling by hikers and other forest recreational users has been implicated in the decline of sensitive forest understory plants (Gross and others 1998).

Research from regions outside of the South has documented shifts in forest bird composition along trails (Hickman 1990, Miller and others 1998, Van der Zande and others 1984). Such effects may depend on the intensity and timing of the recreational disturbance, however (Van der Zand and others 1984).

In other more general studies, research indicates that human intrusion can alter bird behavior and community structure. Disturbance by pedestrians and vehicles was found to reduce the number of bird species on wooded streets, as well as species persistence, guild density, and probability of occupation by individual bird species (Fernadez-Juricic 2000). Crows were found to be more vigilant in areas of high human disturbance than in areas of low human disturbance (Ward and Low 1997). Since vigilance and foraging are mutually exclusive behaviors, the level of human activity can affect the foraging success of sensitive bird species. Others have found, however, that low levels of human intrusion (one person for 1 or 2 hours per week) did not significantly affect the vertical distributions of any forest bird species in three vegetation strata above the ground (Gutzwiller and others 1998). The forest bird species studied were apparently able to tolerate low levels of human intrusion.

Black bears also are sensitive to human disturbance and may be affected by the presence of trails. Hibernating black bears were found to readily abandon their dens and cubs in response to investigator disturbance (Goodrich and Berger 1994).

As observed by Schlauch (1976), some “collectable” wildlife, such as box turtles or salamanders, disappear quickly in the vicinity of ground-level nature trails due to pet collection.

Not all wildlife are disturbed or excluded by trails. Mammalian nest predators, including raccoons, skunks, and coyotes, were observed to be common along trails (Miller and others 1998) and seem to be abundant in edge habitats (Gates and Gysel 1978).

Discussion and Conclusions

Effects of Exotic Plants and Animals

Exotic forest pests, including insects and plant pathogens, have changed the structure of some forest types, and changed the density and composition of wildlife associated with them. Exotic plant species have also displaced native forest trees and understory plants in some areas, but the resultant effects to forest wildlife are not well described. Exotic plants have been introduced to enhance wildlife habitat, but their indiscriminant use in the past has led to serious invasions. Exotic animals have harmed some forest wildlife by displacing native species, preying on native wildlife, or damaging sensitive forest habitats. Only a small percentage of exotic species (4 to 19 percent) have been documented to cause great harm. Another 6 to 53 percent have neutral effects or their effects are not as yet documented.

A large number of potentially invasive exotic species can impact native wildlife and their habitats in the United States. New plant species continue to be imported. Approximately 6,741 plant species are recognized as weeds elsewhere in the world. Only 2,363 occur in the contiguous United States (Westbrooks 1998). In addition, an estimated 26,000 plant species are capable of becoming invasive once they are introduced into new environments (Campbell 1997). Approaches have been recommended for better predicting the invasive potential of exotic plant species (Mack 1996). They include simultaneous field comparisons between cogeners, one naturalized and one native, and following the fate of a species deliberately sown in a natural community beyond its current range, with or without environmental manipulation. Predictions may become better if several approaches are combined simultaneously.

Many of the most invasive plant species across the nation are still offered for sale (Campbell 1997). This is especially true for invasive forest exotics. About 67 percent of invasive forest vines, including kudzu, are still available for purchase along with about 90 percent of the most invasive forest trees. Federal and State governments have no unified policy for limiting entry, reacting to emergency importation threats, or fostering integrated control methods (Miller 1997). No regional agency or organization has clearly defined responsibility or jurisdiction to organize regional integrated weed management programs. Exotic pest plant councils have been formed in an attempt to address this gap, and various Federal agencies have formed the Federal Interagency Committee for Management of Noxious and Exotic Weeds. Control of exotic plants is further complicated by the fact that much of the forest land in the Southeast is privately owned. Less than 18 percent of forested land in the Southern Appalachians is publicly owned (SERAMBO 2000).

Many experts have published recommendations for dealing with the issue of exotic plants and animals (Campbell 1997, Miller 1997, Stein and Flack 1996). Recommendations include:

- Development of more effective ways to prevent new introductions.
- Early detection and eradication of new exotics.
- Better control and management of established invaders.
- Protection and recovery of native species and ecosystems.
- Better public education and support for controlling exotics.
- Better integration of control efforts on the part of responsible government and nongovernmental entities.
- Support for research aimed at identifying invasive species that could potentially damage our forests.
- Support for further research aimed at developing effective ways to control exotics.

Effects of Urbanization

Urbanization has resulted in the loss of forest habitat and fragmentation of forested landscapes. These habitat changes have had the greatest detrimental impacts to specialized forest wildlife species with narrow habitat requirements. Habitat generalists have been better able to adjust to changes brought about by urbanization. Based on the current trends of urbanization across the South, it is likely that forested habitats will continue to be permanently altered, and the amount of available forest habitat will decrease in some areas. Increasing urbanization changes the species diversity, overall abundance, and, more importantly, shifts the species composition of forest wildlife. Some forest wildlife species are especially sensitive to fragmentation, forest edges, and human disturbance. Some species disappear from forest areas even with light levels of urban intrusion. Other species have lost the kind of early successional or quality-disturbed habitats that they require.

For species with area sensitivities, those that require forest interior, those that require specialized habitats, and those intolerant of human disturbance, special management considerations will be needed as urbanization increases in areas of the South. Some species will likely require forest conservation areas with thousands of acres of contiguous habitat to be successfully conserved. Protection may be needed to limit roads and human disturbance in these areas. Barring the feasibility of this conservation approach, finding several adjoining larger tracts or areas connected by corridors may be the next best alternative. To conserve forest wildlife species dependent on early successional habitats, forestry management strategies should be formulated to provide a constant availability of these habitats and provide connective corridors for low-vagility species.

With these considerations in mind, urban wildlife habitats will remain important for some wildlife species as suitable forest habitats decline in some urbanizing areas of the South. Urban wildlife preserves should be planned with the realization that size, habitat composition, connectivity, forest dynamics (management needs), and human perceptions of the preserve will ultimately affect the variety and composition of the species conserved there. Innovative designs in small conservation areas may be needed to avoid creating "ecological traps" for ground-nesting birds.

Effects of Agricultural Land Uses

Agricultural land uses have interrupted the continuity of southern forests, and created forest islands. Wildlife differ in their response to the resulting fragmentation. For some species of birds and small mammals, the forest/agricultural boundary acts as a barrier to movement, fragmenting and isolating populations. The presence of woody, vegetated fencerows may help to facilitate movement of some wildlife, however. Some long distance migrant bird species and species that nest in forest interiors appear to be adversely affected by forest fragmentation particularly in heavily fragmented landscapes with low overall forest cover. The presence of nearby agricultural areas has been shown to reduce the nesting success of some forest bird species. Other taxa of wildlife also exhibit a species-specific response.

Many bird species dependent on open habitats, such as grasslands, prairies, savannas, glades and barrens, are now in serious decline in the Eastern United States. Agricultural areas, especially grasslands and fallow fields, provide habitat for some of these early successional birds and other wildlife, such as eastern cottontails and quail. The presence of vegetated fencerows may further enhance the value of agricultural habitats for some wildlife species while decreasing the value for some grassland species.

Forest wildlife species utilize agricultural areas as foraging habitat. Foraging wildlife can be beneficial for agriculture when they consume insects, mice, or weed seeds. Consumption of crops can also be relatively harmless when it involves consumption of waste grain left behind by mechanical harvesters or consumption of fallen fruit. Still, damage to crops and consumption of agricultural commodities is an important issue, and has resulted in some wildlife species being subjected to lethal and nonlethal depredation control measures. The attraction of wildlife to agricultural areas has also subjected them to injury and death due to faster, more powerful farm machinery, pesticides, and the dangers of other injury and disease.

Old-field successional habitats are important for some wildlife species, but may also serve as introduction points for exotic vegetation into the forest, especially along the edges of forest fragments (Brothers and Spinarn 1992). The former agricultural land use may affect the vegetative structure of the resulting old-field habitat, and restoration to full utility as habitat for forest wildlife may not occur even after a number of years.

Government programs that encourage the removal of land from intensive cultivation, the establishment of stable ground cover for soil conservation, and the deliberate creation of wildlife habitat areas in predominantly agricultural environments can greatly influence the abundance of and diversity of wildlife species (Bolen and Robinson 1995).

Effects of Linear Land Uses (Roads, Power Lines, and Trails)

The effects of roads and power line corridors on forest wildlife are species dependent. For some forest wildlife, the corridors exclude or result in avoidance of the area for distances of 330 feet or more. For grassland and early-successional forest species, roadsides and power line rights-of-way provide valuable habitat, but the value is influenced by the width of the corridor, the nature of the corridor vegetation, maintenance practices in the corridor, and the abruptness of the forest edge. For some forest wildlife species, roads and power line corridors act as barriers, fragmenting populations. Corridors can also act as intraspecific filters, allowing movement of a certain age class or gender. For other species, corridors act as travel lanes, connecting isolated areas of habitat. Unfortunately, roads and power line corridors can also act as travel lanes for the spread of exotic plants and animals. Road mortality for many species of forest wildlife has been well documented. Speed limit, road type, width of the cleared corridor, and other factors affect the mortality levels found on a given highway segment. Roads also have other effects, including mortality due to increased access by legal and illegal hunters, increased pollution along roadsides, and accelerated land use changes along roads.

Wildlife and plants can be affected by the presence of trails through the forest. Trampling by hikers and other outdoor recreationists have been found to cause declines in some sensitive plant species. In addition, shifts in forest bird composition have been documented along trails. Other wildlife, such as bears, are sensitive to human disturbance and may avoid trails. "Collectable" wildlife species may be extirpated from the vicinity of trails due to pet collection.

Needs for Additional Research

Effects of Exotic Plants and Animals

The effects of exotic plant invasions on forest wildlife remain poorly documented. Much of the information available is based on land-manager observations or expert opinions. There is a need for more scientific investigations to systematically document how southern forest wildlife communities on both local and regional scales are affected when forests are invaded by exotic plant species. "Early-warning" research is needed to identify potentially invasive forest exotics to better guide quarantine efforts. Research is needed to develop more effective control and management tools for exotic plants and animals.

Human Land Use Changes

The effects of urbanization and agriculture are better understood for birds than other taxa of forest wildlife. More studies that take place in agricultural and urbanizing areas of southern forests would allow comparisons with avian species studied in other areas of North America. Species responses may differ across their respective ranges.

More information is needed about the effects of land use changes on mammals, herpetofauna, and invertebrates in southern forests to identify species likely to be adversely affected by urbanization.

More studies are needed that document which species are most likely to benefit from connective corridors used to overcome the deleterious effects of fragmentation. More research is needed to determine if corridors have adverse impacts on forest habitats and to identify circumstances under which adverse impacts should be expected.

More information is needed about the breeding success of ground- and low-nesting forest birds in small preserves. Information is needed to formulate management strategies that avoid the creation of "ecological traps" for breeding birds.

Linear Land Uses (Roads, Power Lines, and Trails)

Relatively little data on the effects of roads and power lines on forest wildlife are available for amphibians, reptiles and invertebrates. More information specific to wildlife in southern forests is needed to allow for behavioral differences from one part of a species range to another.

The effect of forest trails on wildlife is better documented for plants than other taxa. More information is needed about wildlife in southern forests.

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Literature Cited

Adams, L.W. 1994. Urban habitats: a landscape perspective. Minneapolis: University of Minnesota Press. 186 p.

Adams, L.W.; Geis, A.D. 1983. Effects of roads on small mammals. Journal of Applied Ecology. 20: 403–415.

Aldrich, J.W.; Coffin, R.W. 1980. Breeding bird populations from forest to suburbia after thirty-seven years. American Birds. 34(1): 3–7.

Allen, C.R.; Demarais, S.; Lutz, R.S. 1994. Red imported fire ant impact on wildlife: an overview. Texas Journal of Science. 46(1): 51–59.

Alsop, F.J., III; Laughlin, T.F. 1991. Changes in the spruce-fir avifauna of Mt. Guyot, Tennessee, 1967–1985. Journal of the Tennessee Academy of Science. 66(4): 207–209.

Anderson, S.H.; Mann, K.; Shugart, H.H., Jr. 1977. The effect of transmission-line corridors on bird populations. American Midland Naturalist. 97: 216–221.

Arcieri, D.T. 1992. Undesirable alien—the house sparrow. The Conservationist. March-April: 24–25.

Ash, A.N. 1997. Disappearance and return of plethodontid salamanders to clearcut plots in the southern Blue Ridge Mountains. Conservation Biology. 11: 983–989.

Ash, A.N. 1999. Clearcuts, salamanders, and field studies. Conservation Biology. 13(1): 206–208.

Askins, R.A. 2001. Sustaining biological diversity in early succesional communities: the challenge of managing unpopular habitats. Wildlife Society Bulletin. 29(2): 407–412.

Askins R.A.; Philbrick, M.J. 1987. Effect of changes in regional forest abundance on the decline and recovery of a forest bird community. Wilson Bulletin. 99(1): 7–21.

Balcom, B.J.; Yahner, R.H. 1996. Microhabitat and landscape characteristics associated with the threatened Allegheny woodrat. Conservation Biology. 10: 515–525.

Barnes, T.G.; Madison, L.A.; Sole, J.D.; Lacki, M.J.; 1995. An assessment of habitat quality for northern bobwhite in tall fescue-dominated fields. Wildlife Society Bulletin. 23(2): 231–237.

Beissinger, S.R.; Osborne, D.R. 1982. Effects of urbanization on avian community organization. Condor. 84: 75–83.

Blair, R.B. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications. 6(2): 506–519.

Blaustein, A.R.; Wake, D.B.; Sousa, W.P. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology. 8: 60–71.

Bloom, P.H.; McCrary, M.D.; Gibson, M.J. 1993. Red-shouldered hawk home-range and habitat use in southern California. Journal of Wildlife Management. 57(2): 258–265.

Bolen, E.G.; Robinson, W.L. 1995. Wildlife ecology and management. Englewood, NJ: Prentice Hall. 620 p.

Bosakowski, T.; Speiser, R.; Smith, D.G.; Niles, L.J. 1993. Loss of Cooper's hawk nesting habitat to suburban development: inadequate protection for a state-endangered species. Journal of Raptor Research. 27(1): 26–30.

Brody, A.J.; Pelton, M.R. 1989. Effects of roads in black bear movements in western North Carolina. Wildlife Society Bulletin. 17(5): 5–10.

Brooks, C.; Hall, D. 2000. Gypsy moth silvicultural guidelines for Wisconsin. PUB–FR–123 97. Wisconsin Department of Natural Resources. http://www.dnr.state.wi.us/org/land/forestry/fh/GM/gmguide.htm. [Date accessed: August 2, 2002].

Brothers, T.S.; Spinarn, A. 1992. Forest fragmentation and alien plant invasion of central Indiana old-growth forests. Conservation Biology. 6(1): 91–100.

Buehler, D.A. 1995. A Geographic Information System to identify potential bald eagle breeding habitat for Southeastern United States rivers and reservoirs. Proceedings of the Annual Conference of Southeastern Associated Fish and Wildlife Agencies. 49: 292–302.

Buehler, D.A.; Mersmann, T.J.; Fraser, J.D.; Seegar, J.K.D. 1991a. Effects of human activity on bald eagle distribution on the northern Chesapeake Bay. Journal of Wildlife Management. 55(2): 282–290.

Buehler, D.A.; Mersmann, T.J.; Fraser, J.D.; Seegar, J.K.D. 1991b. Nonbreeding bald eagle communal and solitary roosting behavior and roost habitat on the northern Chesapeake Bay. Journal of Wildlife Management. 55(2): 273–281.

Butcher, G.S.; Niering, W.A.; Berry, W.J.; Goodwin, R.H. 1981. Equilibrium biogeography and the size of nature preserves: an avian case study. Oecologia. 49: 29–37.

Campbell, F.T. 1997. Testimony for oversight hearing on resident exotic plants and pests threatening the health of our national forests. Given before the House of Representatives, Subcommittee on Forests and Forest Health; June 24. http://www.house.gov/resources/105cong/forests/jun24.97/campbell.htm. [Date accessed: October 4, 2000].

Canterbury, G.E.; Martin, T.E.; Petit, D.R. [and others]. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology. 14: 544–558.

Causey, M.K.; Cude, C.A. 1978. Feral dog predation of the gopher tortoise, *Gopherus polyphemus*, in southeast Alabama. Herpetological Review. 9: 94–95.

Chalfoun, A.D.; Ratnaswamy, M.J.; Thompson, F.R., III. 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecological Applications. 12(3): 858–867.

Chandler, S.K.; Fraser, J.D.; Buehler, D.A.; Seegar, J.D.K. 1995. Perch trees and shoreline development as predictors of bald eagle distribution on Chesapeake Bay. Journal of Wildlife Management. 59(2): 325–332.

Chasko, G.G.; Gates, J.E. 1992. Avian habitat suitability along a transmission-line corridor in an oak-hickory forest region. Wildlife Monograph. 82: 1–41.

Choate, J.R.; Jones, J.K., Jr.; Jones, C. 1994. Handbook of mammals of the South-Central States. Baton Rouge, LA: Louisiana State University Press. 304 p.

Clark, J.D.; Pelton, M.R. 1999. Management of a large carnivore: black bear. In: Peine, J., ed. Ecosystem management for sustainability: priciples [principles] and practices. Boca Raton, FL: St. Lucie Press: 209–223.

Clergeau, P.; Savard, J.L.; Mennechez, G.; Falardeau, G. 1998. Bird abundance and diversity along an urban-rural gradient: a comparative study between two cities on different continents. Condor. 110(3): 413–425.

Clevenger, A.P.; Waltho, N. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Biological Conservation. 14(1): 47–56.

Coker, D.R.; Capen, D.E. 1995. Landscape-level habitat use by brown-headed cowbirds in Vermont. Journal of Wildlife Management. 59(4): 631–637.

Coleman, J.S.; Fraser, J.D. 1989. Habitat use and home ranges of black and turkey vultures. Journal of Wildlife Management. 53(3): 782–792.

Coleman, J.S.; Temple, S.A.; Craven, S.R. 1997. Cats and wildlife—a conservation dilemma. Madison, WI: University of Wisconsin Cooperative Extension. http://wildlife.wisc.edu/extension/catfly3.htm. [Date accessed: October 31, 2000].

Cristoffer, C. 1991. Road mortalities of northern Florida vertebrates. Florida Scientist. 54: 65–68.

Croonquist, M.J.; Brooks, R.P. 1993. Effects of habitat disturbance on bird communities in riparian corridors. Journal of Soil and Water Conservation. 48(1): 65–70.

Cubbedge, A.W.; Nilon, C.H. 1993. Adjacent land use effects on the flood plain forest bird community of Minnesota Valley National Wildlife Refuge. Natural Areas Journal. 13(3): 220.

Danielson, W.R.; DeGraff, R.M.; Miller, T.K. 1997. Rural and suburban forest edges: effect on egg predators and nest predation rates. Landscape and Urban Planning. 38: 25–36.

Debinski, D.M.; Holt, R.D. 2000. A survey and overview of habitat fragmentation experiments. Conservation Biology. 14: 342–355.

DeMaynadier, P.G.; Hunter, M.L., Jr. 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal. 20: 56–65.

Diamond, S.J.; Giles, R.H., Jr.; Kirkpatrick, R.L.; Griffin, G.J. 2000. Hard mast production before and after the chestnut blight. Southern Journal of Applied Forestry. 24(4): 196–201.

Dijak, W.D.; Thompson, F.R., III. 2000. Landscape and edge effects on the distribution of mammalian predators in Missouri. Journal of Wildlife Management. 64(1): 209–216.

Donovan, T.M.; Jones, P.W.; Annand, E.M.; Thompson, F.R., III. 1997. Variation in local-scale edge effects: mechanisms and landscape context. Ecology. 78(7): 2064–2075.

Donovan, T.M.; Thompson, F.R.; Faaborg, J.; Probst, J.R. 1995. Reproductive success of migratory birds in habitat sources and sinks. Conservation Biology. 9(6): 1380–1395.

Dowd, C. 1992. Effect of development on bird species composition of two urban forested wetlands in Staten Island, New York. Journal of Field Ornithology. 63(4): 455–461.

Downes, S.J.; Handasyde, K.A.; Elgar, M.A. 1997a. Use of corridors by mammals in fragmented Australian eucalypt forests. Conservation Biology. 11(3): 718–726.

Downes, S.J.; Handasyde, K.A.; Elgar, M.A. 1997b. Variations in the use of corridors by introduced and native rodents in South-Eastern Australia. Biological Conservation. 82: 379–383.

Drost, C.A.; Fellers, G.M. 2000. Non-native animals on public lands. An on-line article by the United States Geological Service. http://biology.usgs.gov/s+t/noframe/x180.html. [Date accessed: August 2, 2002].

Dunning, J.B., Jr.; Borgella, R., Jr.; Clements, K.; Meffe, G.K. 1995. Patch isolation, corridor effects, and colonization by a resident sparrow in a managed pine woodland. Conservation Biology. 9: 542–550.

Echternacht, A.C.; Harris, L.D. 1993. The fauna and wildlife of the Southeastern United States. In: Martin, W.H.; Boyce, S.G.; Echernacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 81–116.

Engels, T.M.; Sexton, C.W. 1994. Negative correlation of blue jays and golden-cheeked warblers near an urbaninzing area. Conservation Biology. 8(1): 286–290.

Evens, D.R.; Gates, J.E. 1997. Cowbird selection of breeding areas: the role of habitat and bird species abundance. Wilson Bulletin. 109(3): 470–480.

Fernández-Juricic, E. 2000. Avifaunal use of wooded streets in an urban landscape. Conservation Biology. 14: 513–521.

Findlay, S.C.; Bourdages, J. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology. 14(1): 86–94.

Forman, R.T.T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology. 14(1): 31–35.

Forman, R.T.T.; Deblinger, R.D. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. Conservation Biology. 14(1): 36–46.

Foster, M.L.; Humphrey, S.R. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin. 23(1): 95–100.

Franklin, T.M.; Wilkinson, J.R. 1996. Predicted effects in birdlife of two development plans for an urban estate. In: Stenberg, K.; Shaw, W., eds. Wildlife conservation and new residential developments: Proceedings of a national symposium on urban wildlife. School of Renewable Natural Resources, University of Arizona: Tucson, AZ: 105–117.

Friesen, L.E.; Cadman, M.D.; MacKay, R.J. 1999. Nesting success of neotropical migrant songbirds in a highly fragmented landscape. Conservation Biology. 23(2): 338–346.

Friesen, L.E.; Eagles, P.F.; Mackay, R.J. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. Conservation Biology. 9(6): 1408–1414.

Gale, G.A.; Hanners, L.A.; Patton, S.R. 1997. Reproductive success of worm-eating warblers in a forested landscape. Conservation Biology. 11(1): 246–250.

Gates, J.E. 1991. Powerline corridors, edge effects, and wildlife in forested landscapes of the central Appalachians. In: Rodiek, J.E.; Bolen, E.G., eds. Wildlife and habitats in managed landscapes. Washington, DC: Island Press: 12–32.

Gates, J.E.; Gysel, L.W. 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology. 59: 871–883.

Gavareski, C.A. 1976. Relation of park size and vegetation to urban bird populations in Seattle, Washington. Condor. 78: 375–382.

Gehlbach, F.R. 1986. Odd couples of suburbia. Natural History. June: 56–66.

George, W.G. 1974. Domestic cats as predators and factors in winter shortages of raptor prey. The Wilson Bulletin. 86(4): 384–396.

Getz, L.L.; Cole, F.R.; Gates, D.L. 1978. Interstate roadsides as dispersal routes for *Microtus pennsylvanicus*. Journal of Mammalogy. 59(1): 208–212.

Gibbs, J.P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management. 62(2): 584–589.

Goldstein, E.L.; Gross, M.; DeGraaf, R.M. 1986. Breeding birds and vegetation: a quantitative assessment. Urban Ecology. 9: 377–365.

Goodrich, J.M.; Berger, J. 1994. Winter recreation and hibernating black bears *Ursus americanus*. Biological Conservation. 67: 105–110.

Gowaty, P.A. 1984. House sparrows kill eastern bluebirds. Journal of Field Ornithology. 55(3): 378–380.

Grisham, J. 1994. Attack of the fire ant. Bioscience. 44(9): 587–590.

Gross, K.; Lockwood, J.R., III; Frost, C.; Morris, W.F. 1998. Modeling controlled burning and trampling reduction for conservation of *Hudsonia montanta*. Conservation Biology. 12(6): 1291–1301.

Gutzwiller, K.J.; Clements, K.L.; Marcum, H.A. [and others]. 1998. Vertical distibutions of breeding-season birds: is human intrusion influential? Wilson Bulletin. 103(4): 497–503.

Hahn, D.K.; Hatfield, J.S. 1995. Parasitism at the landscape scale: cowbirds prefer forests. Conservation Biology. 9(6): 1415–1424.

Harrison, R.L. 1997. A comparison of gray fox ecology between residential and undeveloped rural landscapes. Journal of Wildlife Management. 61(1): 112–122.

Hartley, M.J.; Hunter, M.L. 1998. A meta-analysis of forest cover, edge effects, and artificial nest predation rates. Conservation Biology. 12(2): 465–469.

Haskell, D.G. 1995. A reevaluation of the effects of forest fragmentation on rates of bird-nest predation. Conservation Biology. 9(5): 1316–1318.

Haskell, D.G. 2000. Effects of forest roads on macroinvertebrate soil fauna of the Southern Appalachian Mountains. Conservation Biology. 14(1): 57–63.

Hellgren, E.C.; Vaughan, M.R. 1994. Conservation and management of isolated black bear populations in the southeastern Coastal Plain of the United States. Proceedings of the Annual Conference of Southeastern Associated Fish and Wildlife Agencies. 48: 276–285.

Hellgren, E.C.; Vaughan, M.R.; Stauffer, D.F. 1991. Macrohabitat use by black bears in a southeastern wetland. Journal of Wildlife Management. 55(3): 442–448.

Heske, E.J. 1995. Mammalian abundances on forest-farm edges versus forest interiors in southern Illinois: is there an edge effect? Journal of Mammalogy. 76(2): 562–586.

Heske, E.J.; Robinson, S.K.; Brawn, J.D. 1999. Predator activity and predation on songbird nests on forest-field edges in east-central Illinois. Landscape Ecology. 14: 345–354.

Hickman, S. 1990. Evidence of edge species attraction to nature trails within deciduous forest. Natural Areas Journal. 10(1): 3–5.

Hines, B.; Anastasi, P.A. 1973. Fifty birds of town and city. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. U.S. Government Printing Office.

Hoffmann, C.O.; Gottschang, J.L. 1997. Numbers, distribution, and movements of a raccoon population in a suburban residential community. Journal of Mammalogy. 58(4): 623–636.

Holt, J. 2000. Changes in bird populations on the Highlands Plateau, North Carolina (U.S.A.), 1946–1995, with emphasis on neotropical migrants. Natural Areas Journal. 20(2): 119–125.

Horn, D.J. 1985. Breeding birds of a central Ohio woodlot in response to succession and urbanization. Ohio Academy of Science. 85(1): 34–40.

Hugo, N. 1989. Honeysuckle. Virginia Wildlife. 50(6): 33.

Huhta, E.; Mappes, T.; Jokimaki, J. 1996. Predation on artificial ground nests in relation to forest fragmentation, agricultural land, and habitat structure. Ecography. 9: 85–91.

Hunter, W.C.; Dixon, J.G.; Pashley, D.N.; Hamel, P.B. 2001a. Bird communities of southern forests. In: Dixon, J.G., ed. Wildlife of southern forests: habitat and management. Blaine, WA: Hancock House Publishers: 322–349.

Hunter, W.C.; Buehler, D.A.; Canterbury, R.A. [and others]. 2001b. Conservation of disturbance-dependent birds in Eastern North America. Wildlife Society Bulletin. 29(2): 440–455.

Inglis, G.; Underwood, A.J. 1992. Comments on some designs proposed for experiments on the biological importance of corridors. Conservation Biology. 6: 581–586.

Ingold, D.J. 1994. Influence of nest-site competition between European starlings and woodpeckers. Wilson Bulletin. 106(2): 227–241.

Ingold, D.J. 1996. Delayed nesting decreases reproductive success in Northern flickers: implications for competition with European starlings. Journal of Field Ornithology. 67(2): 321–326.

Ingold, D.J.; Densmore, R.J. 1992. Competition between European starlings and native woodpeckers for nest cavities in Ohio. Sialia. 14(2): 43–48, 54.

James, D.A.; Neal, J.C. 1986. Arkansas birds, their distribution and abundance. Fayetteville, AR: University of Arkansas Press. [Number of pages unknown].

Jessup, D.A.; Pettan, K.C.; Lowenstine, L.J.; Pederson, N.C. 1993. Feline leukemia virus infection and renal spirochetosis in a free-ranging cougar (*Felis concolor*). Journal of Zoo and Wildlife Medicine. 24(1): 73–79.

Johnsen, E.P.; Dilworth, T.G.; Kehow, P. 1994. Change in waterfowl nest cavity density on a New Brunswick floodplain forest. Ecoscience. 1(3): 271–274.

Johnson, S.R.; Allain, L.K. 1998. Observations of insect use of Chinese tallow [*Sapium sebiferum* (L.) Roxb.] in Louisiana. Castanea. 63(2): 188–189.

Johnson, W.C.; Schreiber, R.K.; Burgess, R.L. 1979. Diversity of small mammals in a powerline right-of-way and adjacent forest in east Tennessee. American Midland Naturalist. 101: 231–235.

Johnston, D.W.; Odum, E.P. 1956. Breeding bird populations in relation to plant succession on the Piedmont of Georgia. Ecology. 37(1): 50–62.

Jones, M.D.; Warburton, G.S.; Pelton, M.R. 1998. Models for predicting occupied black bear habitat in coastal North Carolina. Ursus. 10: 203–207.

Keyser, A.J.; Hill, G.E.; Soehren, E.C. 1998. Effects of forest fragment size, nest density, and proximity to edge on the risk of predation to ground-nesting passerine birds. Conservation Biology. 12: 986–994.

King, D.I.; Griffin, C.R.; Degraaf, R.M. 1996. Effects of clearcutting in habitat use and reproductive success of the ovenbird in forested landscapes. Conservation Biology. 10: 1380–1386.

Kluza, D.A.; Griffin, C.R.; Degraaf, R.M. 2000. Housing developments in rural New England: effects on forest birds. Animal Conservation. 3: 15–26.

Knight, R.L.; Kawashima, J.Y. 1993. Responses of raven and red-tailed hawk populations to linear right-of-ways. Journal of Wildlife Management. 57(2): 266–271.

Kroodsma, R.L. 1982. Edge effect on breeding forest birds along a power-line corridor. Journal of Applied Ecology. 19: 361–370.

Kroodsma, R.L. 1987. Edge effect on breeding birds along power-line corridors in east Tennessee. American Midland Naturalist. 118(2): 275–283.

Kuitunen, M.; Rossi, E.; Stenroos, A. 1998. Do highways influence density of land birds? Environmental Management. 22(2): 297–302.

Lancanster, R.K.; Rees, W.E. 1979. Bird communities and the structure of urban habitats. Canadian Journal of Zoology. 57: 2358–2368.

Liebhold, A.M.; MacDonald, W.L.; Bergdahl, D.; Mastro, V.C. 1995. Invasion by exotic forest pests: a threat to forest ecosystems. Forest Science Monograph. 30. 49 p.

Linehan, J.T.; Jones, R.E.; Longcore, J.R. 1967. Breeding-bird populations on Delaware's urban woodlots. Audubon Field Notes. 21: 641–646.

Long, C.A.; Long, C.F. 1992. Some effects of land use on avian diversity in a Wisconsin's oak-pine savanna and riparian forest. Passenger Pigeon. 54(2): 125–136.

Loos, G.; Kerlinger, P. 1993. Road mortality on saw-whet and screech-owls on the Cape May Peninsula. Journal of Raptor Research. 27(4): 210–213.

MacClintock, L.; Whitcomb, R.F.; Whitcomb, B.L. 1977. Evidence for the value of corridors and minimization of isolation in preservation of biotic diversity. American Birds. 31(1): 6–16.

MacDonald, D.W.; Newdick, M.T. 1982. The distribution and ecology of foxes, *Vulpes vulpes* (L.), in urban areas. In: Bornkamm, R.; Lee, J.A.; Seaward, M.R.D., eds. Urban ecology. The second European ecological symposium. New York: Halsted Press: 123–137.

Machtans, C.S.; Villard, M.A.; Hannon, S.J. 1996. Use of riperian buffer strips as movement corridors by forest birds. Conservation Biology. 10: 1366–1379.

Mack, R.N. 1996. Predicting the identity and fate of plant invaders: emergent and emerging approaches. Biological Conservation. 78: 107–121.

Maddrey, R.C.; Pelton, M.R. 1995. Black bear damage to agricultural crops in coastal North Carolina. In: Proceedings of the Annual Conference of Southeastern Associated Fish and Wildlife Agencies. 49: 570–579.

Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation. 29: 81–96.

Mankin, P.C.; Warner, R.E. 1999. A regional model of the eastern cottontail and land use changes in Illinois. Journal of Wildlife Management. 63(3): 956–963.

Manson, R.H.; Ostfeld, R.S.; Canham, C.D. 1999. Responses of a small mammal community to heterogeneity along forest-old-field edges. Landscape Ecology. 14: 355–367.

Martin, A.C.; Zim, H.S.; Nelson, A.L. 1951. American wildlife and plants. New York: McGraw-Hill Book Company, Inc. 500 p.

Matessi, G.; Bogliani, G. 1999. Effects of nest features and surrounding landscape on predation rates of artificial nests. Bird Study. 46: 184–194.

Meehan, A.L.; Haas, C.A. 1997. Use of a powerline corridor by breeding and wintering birds in Giles County, Virginia. Virginia Journal of Science. 48(4): 259–264.

Meiners, S.J.; Pickett, S.T.A. 1999. Changes in community and population responses across a forest-field gradient. Ecogeography. 22: 261–267.

Menzel, M.A.; Ford, W.M.; Laerm, J.; Krishon, D. 1999. Forest to wildlife opening: habitat gradient analysis among small mammals in the Southern Appalachians. Forest Ecology and Management. 114: 227–232.

Merriam, G.; Kozakiewicz, M.; Tsuchiya, E.; Hawley, K. 1989. Barriers as boundaries for metapopulations and demes of *Peromyscus leucopus* in farm landscapes. Landscape Ecology. 2(4): 227–235.

Michigan State University, Department of Entomology. 1997. Gypsy moth in the forest. Michigan's Gypsy Moth Education Program. East Lansing, MI: Michigan State University. 8 p. http://www.ent.msu.edu/gypsyed/docs/forest.html. [Date accessed: January 22, 2001].

Miller, J.E.; Leopold, B.D. 1992. Population influences: predators. In: Dickson, J.G., ed. The wild turkey: biology and management. Harrisburg, PA: Stackpole Books: 119–128.

Miller, J.H. 1997. Exotic invasive plants in southeastern forests. In: Britton, K.O., ed. Proceedings: exotic pests of eastern forests. Nashville, TN: Tennessee Exotic Pest Plant Council: 97–106.

Miller, S.G.; Knight, R.L.; Miller, C.K. 1998. Influence of recreational trails on breeding bird communities. Ecological Applications. 8(1): 162–169.

Milligan Raedeke, D.A.; Raedeke, K.J. 1995. Wildlife habitat design in urban forest landscapes. In: Bradley, G.A., ed. Urban forest landscapes—integrating multidisciplinary perspectives. [Seattle]: University of Washington Press: 139–149.

Morgan, K.A.; Gates, J.E. 1982. Bird population patterns in forest edge and strip vegetation at Remington Farms, Maryland. Journal of Wildlife Management. 46: 933–944.

Morgan, K.A.; Gates, J.E. 1983. Use of forest edge and strip vegetation by eastern cottontails. Journal of Wildlife Management. 47: 259–264.

Morrell, T.E.; Yahner, R.H. 1994. Habitat characteristics of great horned owls in south-central Pennsylvania. Journal of Raptor Research. 28(3): 164–170.

Natural Resources Defense Council. 2000. End of the road: the adverse ecological impacts of roads and logging: a compilation of independently reviewed research. New York: Natural Resources Defense Council. http://www.nrdc.org/land/forests/roads/intro.asp. [Date accessed: July 26, 2002].

Nelson, D.; Hatten, S.; White, L.; Carey, S. 1992. Distribution of the gopher tortoise *Gopherus polyphemus* in Mobile County, Alabama [Abstract]. Journal of the Alabama Academy of Science. 63(2): 60.

New, J.C., Jr.; Delozier, K.; Barton, C.E. [and others]. 1994. A serologic survey of selected viral and bacterial diseases of European wild hogs, Great Smoky Mountains National Park, U.S.A. Journal of Wildlife Diseases. 30(1): 103–106.

Nuzzo, V. 1997. Invasives on the Web: protecting the native biodiversity of our wild lands from harmful invaders. *Lonicera japonica*. [Abstract]. The Nature Conservancy. http://tncweeds.ucdavis.edu/esadocs/lonijapo.html. [Date accessed: August 22, 2001].

O'Leary, C.H.; Nyberg, D.W. 2000. Treelines between fields reduce the density of grassland birds. Natural Areas Journal. 20(3): 243–249.

Ortega, Y.K.; Capen, D.E. 1999. Effects of forest roads on habitat quality for ovenbirds in a forested landscape. The Auk. 116(4): 937–946.

Osborne, P. 1982. Some effects on Dutch elm disease on nesting farmland birds. Bird Study. 29: 2–16.

Osborne, P. 1983. The influence of Dutch elm disease on bird population trends. Bird Study. 30: 27–38.

Osborne, P. 1985. Some effects of Dutch elm disease on the birds of a Dorset dairy farm. Journal of Applied Ecology. 22: 681–691.

Oxley, D.J.; Fenton, M.B.; Carmody, G.R. 1974. The effects of roads on populations of small mammals. Journal of Applied Ecology. 11: 51–59.

Parendes, L.E.; Jones, J.A. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. Conservation Biology. 14(1): 64–75.

Paton, P.W.C. 1994. The effect of edge on avian nest success: how strong in the evidence? Conservation Biology. 8: 17–26.

Peine, J.D.; Lancia, R. 1990. Control of exotic species: European wild boar. In: Peine, J., ed. Ecosystem management for sustainability: priciples [principles] and practices. Boca Raton, FL: St. Lucie Press: 267–290.

Person, D.K.; Hirth, D.H. 1991. Home range and habitat use of coyotes in a farm region of Vermont. Journal of Wildlife Management. 55(3): 433–441.

Petranka, J.W. 1999. Recovery of salamanders after clearcutting in the Southern Appalachians: a critique of Ash's estimates. Conservation Biology. 13(1): 203–205.

Petranka, J.W.; Eldridge, M.E.; Haley, K.E. 1993. Effects of timber harvesting and Southern Appalachian salamanders. Conservation Biology. 7: 363–370.

Pimentel, D.; Lach, L.; Zuniga, R.; Morrison, D. 1999. Environmental and economic costs associated with nonindigenous species in the United States. Ithaca, NY: Cornell University, College of Agriculture and Life Sciences. 23 p. http://www.news.cornell.edu/releases/Jan99/species_costs.html. [Date accessed: October 4, 2000].

Plant Conservation Alliance—Alien Plant Working Group. 2002. Alien plant invaders of natural areas; fact sheets. http://www.nps.gov/plants/alien/fact.htm. [Date accessed: May 13].

Puglisi, M.J.; Lindzey, J.S.; Bellis, E.D. 1974. Factors associated with highway mortality of white-tailed deer. Journal of Wildlife Management. 38(4): 799–807.

Rabenold, K.N.; Fauth, P.T.; Goodner, B.W. [and others]. 1998. Response of avian communities to disturbance by an exotic insect in spruce-fir forests of the Southern Appalachians. Conservation Ecology. 12(1): 177–189.

Reijnen, R.; Foppen, R.; Braak, C.T.; Thissen, J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology. 32: 187–202.

Reilly, R.E.; Green, H.E. 1974. Deer mortality on a Michigan interstate highway. Journal of Wildlife Management. 38(1): 16–19.

Renne, I.J.; Gauthreaux, S.A., Jr.; Gresham, C.A. 2000. Seed dispersal of the Chinese tallow tree [*Sapium sebiferum* (L.) Roxb.] by birds in coastal South Carolina. American Midland Naturalist. 144: 202–215.

Ribic, C.A.; Warner, R.E.; Mankin, P.C. 1998. Changes in upland wildlife habitat on farmland in Illinois 1920–1987. Environmental Management. 22(2): 303–313.

Rich, A.C.; Dobkin, D.S.; Niles, L.J. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology. 8(4): 1109–1121.

Robbins, C.S. 2001. Non-native birds. http://biology.usgs.gov/s+t/frame/x177.htm. [Date accessed: January 16].

Robbins, C.S.; Dawson, D.K.; Dowell, B.A. 1989. Habitat area requirements of breeding forest birds on the Middle Atlantic States. Wildlife Monographs. 103. 34 p.

Robinson, S.K. 1992. Population dynamics of breeding neotropical migrants in a fragmented Illinois landscape. In: Hagan, J.M., III; Johnson, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, DC: Smithsonian Institution Press: 408–418.

Robinson, S.K.; Thompson, F.R., III; Donovan, T.M. [and others]. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science. 267: 1987–1990.

Roelke, M.E.; Forrester, D.J.; Jacobson, E.R. [and others]. 1993. Seroprevalence of infectious disease agents in free-ranging Florida panthers (*Felis concolor coryi*). Journal of Wildlife Diseases. 29(1): 36–49.

Rose, R.. 1991. The effects of habitat fragmentation and loss on Dismal Swamp mammals. The Virginia Journal of Science. 42(2): 175.

Rottenborn, S.P. 1999. Predicting the impacts of urbanization on riparian bird communities. Biological Conservation. 88: 289–299.

Rudolph, D.C.; Burgdorf, S.J. 1997. Timber rattlesnakes and Louisiana pine snakes of the west Gulf Coastal Plain: hypotheses of decline. Texas Journal of Science. 49(3): 111–122.

Rural Action Inc. 1999. Invasive exotic plants: chart. http://www.ruralaction.org/forestry_invasives_chart.html. [Date accessed: August 2, 2002].

Scharf, C.S.; De Palma, N.K. 1981. Birds and mammals as vectors of the chestnut blight fungus (*Endothia parasitica*). Canadian Journal of Zoology. 59: 1647–1650.

Schlauch, F.C. 1976. City snakes, suburban salamanders. Natural History. 85(5): 46–53.

Scientific American. 1999. Costly interlopers. http://www.sciam.com/explorations/1999/021599animal/index.html. [Date accessed: October 17, 2000].

Sealander, J.A.; Heidt, G.A. 1990. Arkansas mammals: their natural history, classification, and distribution. Fayetteville, AR: The University of Arkansas Press. 308 p.

Seibert, H.C.; Conover, J.H. 1991. Mortality of vertebrates and invertebrates on an Athens County, Ohio, highway. Ohio Journal of Science. 91(4): 163–166.

Shear, T.H.; Lent, T.J.; Fraver, S. 1996. Comparison of restored and mature bottomland hardwood forests of southwestern Kentucky. Restoring Ecology. 4(2): 111–123.

Simberloff, D.; Farr, J.A.; Cox, J.; Mehlman, D.W. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology. 6: 493–504.

Simons, T.R.; Farnsworth, G.L.; Shriner, S.A. 2000. Evaluating Great Smoky Mountains National Park as a population source for the wood thrush. Conservation Biology. 14(4): 1133–1144.

Singer, F.J. 1981. Wild pig populations in the national parks. Environmental Management. 5(3): 263–270.

Smith, R.J.; Schaefer, J.M. 1992. Avian characteristics of an urban riparian strip corridor. Wilson Bulletin. 104(4): 732–738.

Sonenshine, D.E.; Winslow, E.L. 1972. Contrasts in distribution of raccoons in two Virginia localities. Journal of Wildlife Management. 36(3): 838–847.

South Eastern Regional Association of Medical and Biological Organizations. 2000. List of invasive plant species of Southern Appalachia. http://www.main.nc.us/SERAMBO/exotic/index.html. [Date accessed: October 19].

Southwood, T.R.E. 1961. The number of species of insect associated with various trees. Journal of Animal Ecology. 30: 1–8.

Speiser, R.; Bosakowski, T. 1995. Relationships between habitat selection and productivity of red-shouldered hawks in New Jersey and New York [Abstract]. Journal of Raptor Research. 29(1): 66–67.

Stein, B.A.; Flack, S.R., eds. 1996. America's least wanted: alien species invasions of U.S. ecosystems. Arlington, VA: The Nature Conservancy.

Stiles, J.H.; Jones, R.H. 1998. Distribution of the red imported fire ant, *Solenopsis invicta*, in road and powerline habitats. Landscape Ecology. 335: 335–346.

Stover, M.E.; Marks, P.L. 1998. Successional vegetation on abandoned cultivated and pastured land in Tompkins County, New York. Journal of the Torrey Botanical Society. 125(2): 150–164.

Stromayer, K.A.K.; Warren, R.J.; Johnson, A.J. 1998. Chinese privet and the feeding ecology of white-tailed deer: the role of an exotic plant. Journal of Wildlife Management. 62(4): 1321–1329.

Suarez, A.V.; Pfennig, K.S.; Robinson, S.K. 1997. Nesting success of a disturbance-dependent songbird on different kinds of edges. Conservation Biology. 11: 928–935.

Tedders, W.L.; Reilly, C.C.; Wood, B.W. 1990. Behavior of *solenopsis invicta* (Hymenoptera: Formicidae) in pecan orchards. Environmental Entomology. 19(1): 44–53.

Tiebout, H.M.; Anderson, R.A. 1997. A comparison of corridors and intrinsic connectivity to promote dispersal in transient successional landscapes. Conservation Biology. 11(3): 620–627.

Titus, K.; Mosher, J.A. 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. The Auk. 98: 270–281.

Tozzini, F.; Poli, A.; Croce, G.D. 1982. Experimental infection of European wild swine (*Sus scrofa* L.) with pseudorabies virus. Journal of Wildlife Diseases. 18(4): 425–428.

Trombulak, S.C.; Frissell, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology. 14(1): 18–30.

Trzcinski, M.K.; Fahrig, L.; Merriam, G. 1999. Independent effects of forest cover and fragmentation on the distribution of forest birds. Ecological Applications. 9(2): 586–593.

Twedt, D.J.; Portwood, J. 1997. Bottomland hardwood restoration for neotropical migratory birds: are we missing the forest for the trees? Wildlife Society Bulletin. 25(3): 647–652.

Twedt, D.J.; Wilson, R.R. [In press]. Development of oak plantations established for wildlife. Forest Ecology and Management.

Twedt, D.J.; Wilson, R.R.; Best, C. [and others]. [In press]. Habitat restoration for conservation of migratory landbirds: species and local issues. Partner-in-flight workshop: management of migratory landbirds of the Southeast: state of knowledge and research needs.

United States Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States. OTA–F–565. Washington, DC: U.S. Government Printing Office. [Number of pages unknown].

U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita highlands assessment: terrestrial vegetation and wildlife. Rep. 5 of 5. Gen. Tech. Rep. SRS–35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 201 p.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2000. Summary report. 1997 national resources inventory. Ames, IA: Iowa State University Statistical Laboratory. 90 p.

U.S. Fish and Wildlife Service. 1990a. Appalachian northern flying squirrels *(Glaucomys sabrinus fuscus* and *Glaucomys sabrinus coloratus)* recovery plan. Atlanta: U.S. Fish and Wildlife Service. 53 p.

U.S. Fish and Wildlife Service. 1990b. Gopher tortoise recovery plan. Atlanta: U.S. Fish and Wildlife Service. 28 p.

U.S. Fish and Wildlife Service. 1998. Recovery plan for the spruce-fir moss spider. Atlanta: U.S. Fish and Wildlife Service. 22 p.

U.S. Fish and Wildlife Service. 1999. South Florida multi-species recovery plan. Atlanta: U.S. Fish and Wildlife Service. 172 p.

Van der Zande, A.N.; Berkhuizen, J.C.; van Latesreijn, H.C. [and others]. 1984. Impact of outdoor recreation on the density of a number of breeding bird species in woods adjacent to urban residential areas. Biological Conservation. 30: 1–39.

VanDruff, L.W.; Rowse, R.N. 1986. Habitat association of mammals in Syracuse, New York. Urban Ecology. 9: 413–434.

Villard, M.A. 1998. On forest-interior species, edge avoidance, area sensitivity, and dogmas in avian conservation. The Auk. 115(3): 801–805.

Virginia Natural Heritage Program. 2002. Invasive alien plant species of Virginia. Species fact sheets. http://www.dcr.state.va.us/dnh/invlist.htm. [Date accessed: April 10].

Ward, C.; Low, B.S. 1997. Predictors of vigilance for American crows foraging in an urban environment. Wilson Bulletin. 109(3): 481–489.

Warner, R.E. 1992. Nest ecology of grassland passerines on road rights-of-way in central Illinois. Biological Conservation. 59: 1–7.

Wegner, J.F.; Merriam, G. 1979. Movements by birds and small mammals between a wood and adjoining farmland habitats. Journal of Applied Ecology. 16: 349–358.

Weisensel, W.K. 2000. Battered by the airwaves? Wisconsin Natural Resources Magazine. February, 2000. http://www.wnrmag.com/stories/2000/feb00/birdtower.htm. [Date accessed: October 30].

Weitzel, N.H. 1988. Nest-site competition between the European starling and native breeding birds in northwestern Nevada. The Condor. 90: 515–517.

Westbrooks, R. 1998. Invasive plants, changing the landscape of America: fact book.Washington, DC: Federal Interagency Committee for the Management of Noxious and Exotic Weeds. 109 p.

Whelan, C.J.; Dilger, M.L. 1992. Invasive, exotic shrubs: a paradox for natural area land managers? Natural Areas Journal. 12(2): 109–110.

Whitcomb, R.F.; Robbins C.S.; Lynch, J.F.; 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. In: Burgess, R.L.; Sharpe, D.M., eds. Forest island dynamics on man-dominated landscapes. New York: Springer-Verlag: 125–205.

White, D.; Kendall, K.C.; Picton, H.D. 1999. Potential energetic effects of mountain climbers on foraging grizzly bears. Wildlife Society Bulletin. 27(1): 146–151.

White, S.B.; Dolbeer, R.A.; Bookhout, T.A. 1985. Ecology, bioenergetics, and agricultural impacts of a winter-roosting population of blackbirds and starlings. Wildlife Monograph. 93. 42 p.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology. 66(4): 1211–1214.

Wilcove, D.S. 1988. Changes in the avifauna of the Great Smoky Mountains: 1947–1983. Wilson Bulletin. 100(2): 256–271.

Wilcove, D.S.; Rothstein, D.; Dubow, J. [and others]. 1998. Quantifying threats to imperiled species in the United States. Bioscience. 48(8): 607–615.

Williams, C.E.; Ralley, J.J.; Taylor, D.H. 1992. Consumption of seeds of the invasive Amur honeysuckle, *Lonicera maackii* (Rupr.) Maxim. by small mammals. Natural Areas Journal. 12(2): 86–89.

Yahner, R.H. 1983. Population dynamics of small mammals in farmstead shelterbelts. Journal of Mammalogy. 64(3): 350–386.

Yahner, R.H. 1988. Changes in wildlife communities near edges. Conservation Biology. 2(4): 333–339.

Yahner, R.H. 1996. Forest fragmentation, artificial nest studies, and predator abundance. Conservation Biology. 10: 672–673.

Yahner, R.H.; Mahan, C.G. 1996. Depredation on artificial ground nest in a managed, forested landscape. Conservation Biology. 10(1): 285–288.

Yates, S.W.; Sisson, D.C.; Stribling, H.L.; Speake, D.W. 1995. Northern bobwhite brood habitat use in south Georgia. In: Proceedings of the Annual Conference of Southeastern Associated Fish and Wildlife Agencies. 49: 498–504.

Yosef, R. 1994. The effects of fencelines on the reproductive success of loggerhead shrikes. Conservation Biology. 8: 281–285.

Zimmerman, J.H. 1991. Habitat preferences. In: Robins, S.D., Jr., ed. Wisconsin birdlife: population and distribution past and present. Madison, WI: University of Wisconsin Press: 615–650.

Chapter 4: Effects of Forest Management On Terrestrial Ecosystems

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What are the historical and projected future impacts of forest management and access on terrestrial ecosystems in the South?

Key Findings

- Changes in land use, particularly reductions in the use of fire, have altered the structure and composition of southern forests and associated wildlife communities.
- Retaining structural elements, such as a few mature trees and snags, in young, even-aged stands provides many benefits for a variety of wildlife species.
- Early successional stands promote diversity in plant and animal communities, but many of the beneficial aspects are negated when the canopies of these stands close.
- Stands receiving silvicultural treatments that promote complex forest canopies are heavily utilized by a variety of bird species.
- A shift in intermediate stand treatments from prescribed fire to herbicides has led to widespread changes in forest structure.

Introduction

Wildlife communities are important components of southern forests (Dickson 2001). Many wildlife species have the potential to impact forest structure and species composition, and they are all affected by forest disturbance. Forest disturbance may be human-induced through prescribed burning, silvicultural treatments, or road building; or natural, by storms, insects and disease, or wildfire. These disturbance mechanisms influence forest communities by locally setting back succession. With fire, succession can be arrested at a desired point. With clearcuts, forest communities may be brought back to stand initiation and allowed to make the transition through several successional stages.

A diverse array of wildlife species exists in southern forests. Each species requires certain forest types and successional stages. Many species thrive in early successional habitat, while others require mature forests to maintain viable populations. Proper forest management has the potential to benefit a variety of wildlife species by providing a variety of forest conditions in many successional stages.

Many wildlife species or populations impact the environment in which they live. For example, white-tailed deer can affect midstory growth and tree species reproduction by overbrowsing. Beavers, which are now common in many southern forests, can impact forest communities by flooding the land. Other rodents can have major impacts by feeding on acorns in artificially reforested areas. Birds disperse the seeds of many plant species, potentially adding to plant diversity or introducing exotic species.

Relationships between animal communities and plant communities are complex. Any forest-community disturbance has the potential to positively impact some wildlife species and negatively impact others.

Wildlife communities are most affected by forest structure and species composition. Forest management, by nature, impacts these variables to produce desirable conditions for wood production. Since wildlife are dependent on the plant communities where they live, the bulk of this chapter addresses the impacts of forest management on native plant communities and subsequent effects on wildlife. Much attention is devoted to the ecology of southern forest plant communities.

Methods

This chapter reviews current scientific literature related to the impacts of forest management on terrestrial ecosystems.

Data Sources

Sources of data used in compiling this chapter are referenced throughout the text and listed in the literature cited section.

Results

Historical Perspective

To fully understand the ecology of southern terrestrial forested ecosystems today, a brief outline of the evolutionary changes of forested ecosystems in the South during the last 20,000 years is important (Bonnicksen 2000, Buckner and Turrill 1999, Delcourt and Delcourt 1998; also see chapter 2). At the height of the Wisconsian glaciation, southern forest communities were shifted further south than they are today. Oak-hickory, southern pine, and forested wetlands in particular were mostly restricted to the coastline of the Gulf of Mexico and the lower Atlantic Coast. Much of the interior, north of oak-hickory-southern pine dominated areas but south of the ice sheets, was dominated by spruce, fir, jack pine, and northern hardwood forest communities. The exact nature and condition of these forests and disturbance regimes are unknown, but the presence of large grazing herbivores and fire-adapted forest communities suggests that much of this forest land was relatively open and subject to regular disturbances (Bonnicksen 2000).

The distribution of southern forest communities began to resemble what we find today by 10,000 years before present. Spruce, fir, and northern hardwoods became restricted to the highest elevations in the Appalachians, and mixed hardwoods dominated the interior of the South. Southern pine and forested wetland communities spread northward as the glaciers retreated.

Thriving Native American communities existed over virtually all of the South, and they depended heavily on the surrounding ecosystems. Indigenous people impacted the landscape to suit their way of life. They often burned forests to drive game animals, cleared land for rudimentary agriculture, and enhanced habitat for both wildlife and people. Although cultures changed during this 10,000-year period from nomadic people to the larger and more permanent societies, human-induced disturbances were widespread throughout the region at all times during the period up until the first European contact (Bonnicksen 2000). The occurrence of these human-induced disturbances, combined with natural fires, storms, flooding, and grazing suggest the southern landscape was not composed of expansive closed canopied forests as is often suggested (Beilman and Brenner 1951, Hamel and Buckner 1998, Lee and Norden 1996).

Before European settlement, fire was a major force in shaping forest structure. Frost (1998) estimated fire frequencies at 1 to 3 years in Peninsular Florida and the lower Coastal Plain and 4 to 12 years in the Piedmont, upper Coastal Plain, Ozarks, Interior Low Plateaus, and Ouachita Mountains. The frequency of presettlement fire in the Appalachians was 7 to 25 years in most areas but 26 to 100 years in protective coves and in the Cumberland Mountains.

Only recently have scientists fully understood the importance of Native American burning in southern ecosystems. (Buckner and Turrill 1999, Delcourt and Delcourt 1997, Gross and others 1998, Williams 1998). The primary reason for this late understanding is that the Native American population when settlers arrived was vastly underestimated. Pandemics decimated Native American populations soon after Europeans arrived, and their influence on the southern landscape was reduced accordingly. Between 1500 and 1800, cultural disturbance regimes were severely altered. As a result, mosaics of forest and grassland types, including a variety of successional communities, became closed forests (Buckner and Turrill 1999). Pollen analysis of several old-growth forests in New England show that these forests developed after 1700; prior to that, these sites supported frequently disturbed communities (McLachlan and others 2000). The degree to which relict “old-growth” forest communities in the Southeast, especially what are thought to be relict hemlock stands, follow this same pattern is yet to be determined.

Despite the loss of human-induced disturbances from 1500 to 1800, explorers, naturalists, and settlers still reported expansive savannas and open woodlands in the Piedmont, Appalachians, and Interior Low Plateaus (Barden 2000, Bartram 1998, Belue 1996). In western North Carolina, Bartram in 1775 described both “high” forest (presumably closed stands) and expansive open areas, including grassy plains with scattered large trees at over 5,000 feet in elevation. Barden (2000) discusses the map made by the French cartographer Delisle in 1718 depicting the “Grande Savane” covering most of South Carolina’s (and some of North Carolina’s) Piedmont region. This map corresponds well with settlers’ descriptions in 1752 of “blackjack savannas” and the occurrence of many fire-adapted plants usually associated with prairies (Nelson 1992).

Several large tracts of native prairie existed in the Interior Low Plateaus (south-central Kentucky and adjacent Tennessee) and across the Coastal Plain in what is now Georgia, Alabama, Mississippi, and Arkansas. Two of the largest southern prairies on the Coastal Plain were the Blackbelt Prairie in the Central Gulf Region and the Grand Prairie within the Mississippi Alluvial Plain. All native prairies were perpetuated by fire.

Most of the pinelands on the Coastal Plain were burned periodically, reducing stand density and supporting a rich herbaceous layer of grasses and forbs. The influence of fire on southern forests is covered in detail in chapter 25 of this report. The habitat conditions in Eastern North America supported bison and elk herds, as well as wolves, during the first three centuries after Columbus.

By 1800, however, bison, elk, and gray wolves were extirpated in the South; beaver were nearly trapped out; and the influence of a temporary resurgent Native American influence was waning. As European-Americans spread across the South during the 1800s, they cleared forests for their settlements and agriculture on a larger scale than Native Americans had ever undertaken. Subsequent rapid population growth led to indiscriminate decimation of wildlife populations.

Under the “new management,” the frequency of burning increased. Many areas were burned annually to provide spring forage for ranging livestock. Especially in the Appalachians, the combination of increased frequency of fire and livestock grazing had many undesirable effects. Trees failed to regenerate and erosion increased on steep slopes (Ayers and Ashe 1905).

By the early 1900s, most old-growth longleaf pine had been logged. Most upland hardwoods outside the steep Appalachian Mountains had been logged and cleared for farming. Control of large predators to protect livestock severely reduced populations of several large predators, including mountain lions, black bears, and red wolves. Hunting and selling wildlife was common and had detrimental effects on white-tailed deer, bison, wild turkeys, passenger pigeons, Carolina parakeets, waterfowl, and others (chapter 1). Introduced plant diseases eradicated plant species from much of their native range, drastically reducing carrying capacity for many wildlife species (Diamond and others 2000) (chapter 3). Land was cleared for plowing over much of the South. Rice, tobacco, and cotton were major cash crops. Especially on marginal sites, farming led to massive and widespread soil erosion (Reynolds 1980).

As steam and gasoline powered machinery became available, large-scale drainage and flood control projects were completed. With flooding controlled and wetlands drained, over 30 million acres of bottomland hardwood forests were cleared for agriculture. By the 1940s, the last great bottomland forests, which were in the Mississippi Alluvial Plain and in Florida, were logged over in support of the War effort. Effects on wildlife were profound. For example, the last population of ivory-billed woodpeckers in the United States was destroyed. These changes impacted not only wildlife populations but also ecosystem resiliency. Immediately after clearing, these "new lands" were highly productive for agriculture, but many sites were depleted of nutrients after several years of cropping and erosion. Before agriculture and water control, these former forested wetlands benefited from annual soil nutrient deposition from flooding and high organic content from forest biomass. Draining and clearing compromised the natural soil recharge mechanisms. It has been demonstrated that bottomlands previously in agriculture are not as productive for forest growth as those that have remained in forests (Baker and Broadfoot 1979).

Due to difficult access, most steep mountain slopes were spared until the beginning of the 20th century. Then technology and transportation advances made steep mountainous slopes economically accessible. Logging practices changed from commercial high-grading, which was changing tree species composition, to commercial clearcutting, with little attention to sustainable practices. Between 1900 and 1930, most of the steep mountain slopes were logged, dramatically changing the nature of Appalachian forests.

During the first half of the 1900s, the amount of forested acreage was at its all time low; but the Great Depression, the boll weevil, diseases like tobacco mosaic virus, and the introduction of high-yield agriculture led to wide-scale abandonment of unprofitable farms. Through tree planting and natural seeding, abandoned agricultural fields and logged-over lands reverted to forest during the 1950s and 1960s. Southern forests recovered much of their lost acreage. As part of recovery efforts, use of fire was restricted and fire was suppressed. The use of prescribed fire, even where appropriate, became rare in the South (Croker 1987, Frost 1993). As a result, hardwood encroached into prairies and pinelands, and forests became denser all across the South. Fire suppression, extensive and unregulated clearcutting, and losses of important species like American chestnut to exotic diseases and pests, greatly altered forest conditions throughout the South.

Now, there is a growing realization that limiting fire use across the South has been detrimental to biotic diversity (Buckner and Turrill 1999; Frost 1995, 1998). However, increasing urbanization and increasing density of major roads create liability risks that may doom widespread prescribed burning for silvicultural purposes. In addition, recent industrial forest economic studies indicate that frequent burning causes some slowing of true growth rates.

Today there are more forested acres in the South than in the early 1900s. These forests, however, are greatly altered from forests encountered by European settlers. And the forests cleared by European settlers differed from those used for thousands of years by Native Americans. The common theme for the last 10,000 years is that forests were managed to meet human needs, including those of Native Americans.

Many of the forest wildlife and plant species now listed as endangered or threatened are suffering from the effects of changes in the last 500 years in conditions that existed for the previous 10,000 years. Lost forest acreage has been recovered over the last 50 years, but the new forests are not the same as those that existed for 10,000 years. Development activities and some management practices are not favorable for maintaining many species or for maintaining the integrity of southern terrestrial ecosystems.

One important lesson from the last 10,000 years of southern history, along with recent research results, is that "hands-off" management of extensive areas of southern wildland must be viewed and implemented with caution. Preservation of pristine and functioning ecosystems is an important conservation goal, but such situations are now very rare in the Southeast. Attempts to remove all human influences from some wildlands in the Southeast may appear to be an attractive conservation strategy. They certainly promote other nonconservation values, such as solitude and unique recreational opportunities. We should recognize, however, that removal of all human disturbances will have profound effects on the region's biota. Certainly, "hands-off" management in one area will not necessarily counterbalance intensive management elsewhere. To avoid regional population declines and species losses, land managers must have the flexibility to promote active management. This region's biota does not thrive in a static system, and intentional neglect does nothing but promote additional extinctions and endangerment to species at risk (for example, see Askins 2001, Barden 2000, Buckner and Turrill 1999, Cook 2000, Gross and others 1998, Holmes and Sherry 2001, Hunter and others 2001, Saenz and others 2001). This flexibility should not extend to the other extreme of promoting intensive forestry for wildlife conservation, but it does suggest that some level of active management will be necessary to maintain many still extant but imperiled species, including many found on present or proposed set-aside lands.

Wildlife and Forest Management

Landscape context issues— It is very important to view terrestrial ecosystems at a landscape level. Substantial research has been done on the effects surrounding landscapes have on the health and status of migratory birds, salamanders, and black bears. Below are summaries of our present understanding of the complex relationships for these groups of species.

Landscape context issues: migratory birds— Since the 1970s, biologists have been documenting the decline of migratory bird species from isolated woodlots and parks nestled in agricultural- or urban-dominated landscapes in the Midwestern and Northeastern United States (Harris 1984, Robbins and others 1989, Robinson 1992, Temple and Cary 1988, Terborgh 1989). These local declines have been attributed to forest fragmentation, where negative effects on populations occur due to increasing isolation of what otherwise should be suitable habitat.

Among the negative effects, the best documented are factors that reduce reproductive success, especially those associated with elevated nest predator and nest parasites like the brown-headed cowbird populations (Brittingham and Temple 1983, Dijak and Thompson 2000, Gates and Gysel 1978, Keyser and others 1998, Rich and others 1994, Robinson 1992, Wilcove 1985). However, for birds that have high dispersal capabilities, it is theoretically possible for “sink” populations—those with reproduction below which a populations can be sustained—to be large and seemingly “stable” (Pulliam 1988). The persistence of some migratory bird populations in the face of reduced reproductive success is usually explained by the immigration of individuals from more secure populations (Robinson 1992). These more secure “source” populations of forest birds, where reproduction supports a surplus of individuals, presumably are from more largely forested landscapes. In theory, the more isolated the sink population from source populations, the more likely that sink population will eventually collapse.

Other factors associated with forest fragmentation may affect birds, but are more important for other wildlife species less able to widely disperse. These other factors include: (1) increased mortality of individuals moving between patches, (2) lower recolonization rates of empty patches, and (3) reduced local population sizes resulting in increased susceptibility of species to regional extirpation or rangewide extinction (Trzcinski and others 1999). Recent studies also have documented reduction of food or other vital factors in forest fragments compared with larger, more intact habitats (Burke and Nol 1998).

Many of the negative effects to birds from forest fragmentation are associated with edges between habitat types. Edges between major habitat types can be extremely productive in terms of diversity of cover and food resources. However, predator and cowbird populations often are elevated in edges. Therefore, nesting birds that are attracted to habitat near edges may be overwhelmed by predators or cowbirds. Gates and Gysel (1978) coined the term “ecological trap” to describe situations where nesting attempts are doomed to failure (also see Donovan and Thompson 2001).

Area-sensitive species do not occur in habitat patches below a certain size. Forest-interior species are usually found in extensive areas of forest interior rather than a diversity of successional stages (Ambuel and Temple 1983, Blake and Karr 1987, Freemark and Collins 1992). However, whether any one species is area-sensitive or associated only with forest interiors varies considerably from place to place, often with respect to the surrounding land use patterns.

Most of the studies cited above were done in the Midwest and Northeast. Relatively few studies in the Southeast have duplicated the long-term studies in other regions, but there is no obvious reason not to apply findings in the Southeast [see *Southern Appalachian Assessment* (Southern Appalachian Man and the Biosphere 1996) and *Ozark-Ouachita Highlands Assessment* (U.S. Department of Agriculture Forest Service 1999)]. Results of forest fragmentation studies from landscapes dominated by agriculture and development, however, are not easily transferred to landscapes dominated largely by forest, whether actively or passively managed (Donovan and others 1997; Farnsworth and Simons 1999; Gale and others 1997; Graves 1997; Hagan and others 1996, 1997; Harris and Reed 2001; King and others 1996; Lichstein and others 2002; Marzluff and Ewing 2001; Robinson and others 1995; Simons and others 2000; Wilcove 1988).

Meta-analysis of bird studies across the Midwest suggests that as long as 70 percent forest cover is maintained in largely forested regions, daily nesting survival rates are sufficient to support source populations (Donovan and others 1997, Robinson and others 1995). Where forest cover falls below 70 percent, these and other data suggest that populations may not be sustainable, but large forest patches within a more fragmented landscape may be still able to support healthy populations. Thus, the larger the patch the more species can be supported locally (Robinson 1996).

There is little evidence of negative effects on forest birds in habitats fragmented by various silvicultural methods and associated land uses like temporary roads (Barber and others 2001, Dugay and others 2001, Hartley and Hunter 1998, Villard 1998). There are exceptions involving subtle negative edge effects for otherwise common, stable or increasing, and widespread bird species (Flashpohler and others 2001a, 2001b; Haskell 2000; Manolis and others 2000; Ortega and Capen 1999; Pornezuli and Faaborg 1999; Pornezuli and others 1993; Rosenberg and others 1999), which may reflect subtle changes in habitat condition—more so than habitat fragmentation. On balance forest bird conservation does not have to be focused on fragmentation issues in the Southeast, where overall forest cover exceeds 70 percent in entire physiographic areas (Southern Appalachian Man and the Biosphere 1996, U.S. Department of Agriculture Forest Service 1999).

Therefore, fragmentation is not considered a serious issue for migratory birds in the southern Blue Ridge and northern Cumberland Plateau and Mountains within the Appalachians and much of the Ozark and Ouachita Mountains (Hunter and others 2001). Even in these largely forested areas, local fragmentation due to urbanization may occur, as demonstrated in the southern Blue Ridge and Ozarks (Fitzgerald and others, in press; Holt 2000). Forest fragmentation from agriculture and development is most serious in the Ridge and Valley within the Appalachians, the Piedmont Plateau, the Interior Low Plateaus (outside the western Highland Rim), and the Mississippi Alluvial Plain. Much of the Coastal Plain is intermediate in its percentage of forest land cover, with forest concentrated along the lower Coastal Plain and along major river systems, often including large forest industry tracts.

Landscape context issues: salamanders—Pond-breeding salamanders require access from terrestrial habitats to vernal ponds or Carolina bays. Based on a literature review, Semlitsch (1998) recommended for several species of *Ambystoma* salamanders that buffers around breeding ponds extend to over 160 m (500 feet) and suggested that these areas provide for foraging, growth, maturation, and maintenance. However, even this strategy may not ensure population stability or dispersal among populations unless corridors or connections across the landscape are maintained. Corridors are vital if the surrounding land is hostile to salamander dispersal when timber is removed.

Chazal and Niewiarowski (1998) kept recently metamorphosed mole salamanders in field enclosures. No detrimental effects were detected for animals in recent clearcuts compared to animals in 40-year-old pine stands. These authors hypothesized that the removal of vegetation may not be as detrimental as the mechanical process by which the vegetation is removed. In contrast, Means and others (1996) show that conversion from a relatively open longleaf-wiregrass community, subject to regular burning, to a densely stocked and bedded slash pine plantation can be extremely detrimental for dispersal and access to breeding ponds by the federally threatened flatwoods salamander.

For Plethodontid (woodland) salamanders, there is much conflicting interpretation of data on population responses to clearcutting in montane habitats (Ash 1997, Ash and Pollack 1999, Herbeck and Larsen 1999, Petranka 1999, Petranka and others 1993). Steady return of populations to preharvest levels suggests that fragmentation in largely forested areas is not a serious problem. However, net change in habitat quality may be a serious issue. Important habitat components like substantial coarse downed woody material may be lacking in young stands. Failure of woodland salamanders to reoccupy suitable habitat as it develops or local declines occurring in suitable habitat would be evidence of effects associated with habitat fragmentation, which could lead to population collapse. Thus far, failure of woodland salamanders to reoccupy treated stands remains undocumented, but time lapses may be unacceptably long and the densities reached may be unacceptably low for more vulnerable species.

Fragmentation by roads can seriously restrict movement of amphibian populations. Amphibians on roads die from exposure to predators or are run over by vehicles. Indirect mortality results from lack of suitable habitat facilitating dispersal across roads. Generally, roads of any width and use likely provide some barrier to dispersal. Working in a fragmented landscape, Gibbs (1998) found that most species avoided road-forest edges, but these same species were not inhibited from crossing from forest into fields to reach breeding ponds. In another study by deMaynadier and Hunter (2000), anurans (frogs and toads) were not inhibited from crossing either narrow (5 m) or wide (12 m) roads in a forested landscape; salamanders were inhibited from crossing the wider roads. Thus, in the latter study, wide roads apparently separated salamanders into subpopulations.

Landscape context issues: black bears—Black bears in the Southeast receive a substantial amount of management attention. In addition to a federally listed subspecies in Louisiana, another potentially vulnerable population occurs in Florida. Other healthier populations are subject to hunting that requires careful management attention. Two concerns have been raised about habitat fragmentation for this species: (1) the amount of forested habitat (with a wide range of successional conditions) needed to support a healthy population, and (2) the road density that is too high to sustain a population. In the Coastal Plain, Peninsular Florida, and the Mississippi Alluvial Plain, for example, successful restoration and active management of all the major forested wetland systems would provide significant progress toward what is deemed necessary to secure black bear populations from southeastern North Carolina to Texas.

About 40,000 ha (100,000 acres) of bottomlands, in largely forested condition, are needed to support a population of between 50 and 200 bears, depending on the quality of the habitat (Rudis and Tansey 1995). By the same criteria, a population of about 1,000 black bears would require between 140,000 ha (350,000 acres) and 1,600,000 ha (4,000,000 acres). These areas could include substantial agricultural acreage. Land planted in grain crops is extensively used by black bears as long as escape cover is nearby.

Existing montane population centers such as the southern Blue Ridge in the Appalachians, the Ozarks, and the Ouachitas do not require a minimum acreage to support a healthy population, but bears may avoid heavily used roads or such roads may cause significant mortality (Clark and Pelton 1999). Narrow and infrequently used roads, however, may be heavily used by bears as movement corridors. Road edges that receive direct sunlight may provide substantial amounts of soft mast (fruit) where otherwise closed canopy forests make this important food source rare (Perry and others 2000). Management of narrow or temporary roads (closures and day-lighting) may be more important than the density of such roads in largely forested landscapes.

Landscape context issues: other biota and summary—Fragmentation is a serious problem in shrub-scrub and grassland as well as forest habitat. In fact, many more species are at risk because of fragmentation of shrub-scrub and grassland habitats, rather than with mature forest habitats (Brawn and others 2001, Hunter and others 2001, Larem 1996, Lee and Norden 1996, Litvaitis 1993, Litvaitis and others 1999, Litvaitis and Villafuerte 1996, McCoy and Mushinsky 1999, Opler and Krizek 1984, Woolfendon 1996). These isolated patches of shrub-scrub and grassland habitat may be in agricultural or developed landscapes as well as in forest-dominated landscapes where stocking density has increased (Dunning and others 1995, Means and others 1996).

The challenge for land managers is to improve habitat conditions for a broad array of grassland, shrub-scrub, and mature forest species. Because of differences in land values, this challenge is theoretically more easily met in largely forested areas than in agricultural and developed areas. In heavily fragmented landscapes, attempts to improve habitat conditions for priority species may require segregation of species that depend on mature forests from species that require early successional or shrub-scrub or grassland habitat conditions.

Habitat content (composition and structure) issues—Forest management may contribute to fragmentation of a variety of landscapes, but its effects in forested-dominated landscapes are the most complex. Forest management is designed to influence the composition and structure of forests. Changes in wildlife habitat can be viewed as side effects. As with fragmentation effects, most of the research on habitat relationships in Eastern North America associated with forest management involves migratory birds.

During the latter part of the 20th century, forest cover increased in Eastern North America, while populations of many nearctic-neotropical migratory birds declined. Some researchers speculated that declines were largely attributable to accelerating loss of tropical "wintering" habitats (Robbins and others 1989b, Terborgh 1989). Losses of wintering habitat undoubtedly contributed to declines for a number of species. Recent work suggests, however, that most species of nearctic-neotropical migrants are flexible in use of tropical secondary forest [including especially shade-grown coffee and cacao (chocolate) plantations] and successional habitats (for example, see Krichner and Davis 1992, Sherry 2000).

Another bit of evidence implicating changes in the United States is the substantial variation among south-eastern physiographic areas in population trends for many forest species. Among wood-warbler species, declines have been steepest in the heavily forested interior physiographic areas, while populations in the more fragmented and heavily managed lowland physiographic areas have increased (Coastal Plain, Piedmont, Mississippi Alluvial Plain) (James and others 1996). One possible explanation that has not been explored thoroughly is that many forest bird populations may be responding to differences in forest conditions that have developed over the last 30 years (Askins 2001; Hunter and others 2001, in press; Holmes and Sherry 2001; Kilgo and others 1996).

Much of the forest cover increase in the Southeast has been through the expansion of short-rotation pine plantations and the increasing dominance of midsuccessional hardwoods that do not provide high quality habitat for forest migratory birds. (Askins and others 2001, Hunter and others 2001, Trani and others 2001). These phenomena may explain declining population trends in interior physiographic areas. They do not explain the population increases in lowland physiographic areas.

Habitat content (composition and structure) issues: migratory birds in forested wetlands in lowland physiographic areas—Most of the forest loss in bottomland areas outside the Mississippi Alluvial Plain occurred before the initiation of the Breeding Bird Survey (mid-1960s), so there may have been some response to the return of forests in the Southeast after the 1960s. Substantial losses of forested wetlands in the Mississippi Alluvial Plain during the 1960s and 1970s were attributable to increasing soybean prices. For migratory birds associated with forested wetlands, populations have been stable or increasing while there was a substantial reduction in mature forested wetlands and an increase in younger age classes during the last few decades (Hefner and others 1995, James and others 1996, see chapter 20).

In recent years, close to 100,000 acres of forested wetland in the Southeast have been drained and converted to farmland, pine or hardwood plantations, and industrial and commercial development (Sharitz and Mitsch 1993). In the Southeast, about 45 million acres were once covered by floodplain forests. About 37 million acres remained in 1952, and 33 million acres in 1975. Since then, an additional 2 million acres of forested wetlands were converted to nonwetland uses and another 1 million acres were converted to other wetland types (Hefner and others 1995). Thus, about 30 million acres of forested wetlands remained by 1985. Overall, about 30 percent of the Southeast's historical forested wetlands have been lost. In the Mississippi Alluvial Plain, losses approach 80 percent.

Most of the 70 percent of South-eastern forested wetlands that remain have been cutover at least once, and many are severely fragmented. This fragmentation has further contributed to the decline of many rare but wide-ranging species in the Southeast. Forest-interior and area-sensitive species and those that require large tracts of mature and over-mature wetland forests have been particularly hard hit.

Shrub-scrub (short) and forested (tall) pocosins and Carolina bays support large numbers of bird and amphibian species (Lee 1986, 1987; Moler and Franz 1987). Pocosins and Carolina bays occur in the South Atlantic Coastal Plain of North and South Carolina and Georgia. Originally, pocosin communities in the Southeast covered some 3.5 million acres, about 70 percent are in North Carolina (Richardson and Gibbons 1993). Considerably less than one-third of the original acreage now can be considered intact; another one-third have been irrevocably altered (Richardson and Gibbons 1993). There were probably between 10,000 and 20,000 Carolina bays prior to European colonization, the vast majority in South Carolina. Presently, few Carolina bays can be considered untouched by deleterious human activities. Both pocosins and Carolina bays have been converted to farmland or tree plantations (principally pine) or mined for peat. Areas around Carolina bays are also highly susceptible to commercial and residential development (Richardson and Gibbons 1993).

In the South Atlantic Coastal Plain of North and South Carolina, serious concerns have been raised about conversion of naturally occurring forested woodlands, especially pocosins, to bedded loblolly pine plantations or short rotation forested wetlands. In this case, the presumption was that many species of migratory birds would be significantly harmed by this conversion. However, populations of a majority of these species have been stable or increasing, especially in North Carolina where much of the concern about conversion has been concentrated.

There are many inherent reasons to be concerned about pocosin conversion to pine plantations (Moler and Franz 1987), but migratory birds may be faring relatively well [see section "Habitat content (composition and structure) issues: summary assessment of wildlife use of pine plantations" for more discussion]. Among the species that partially or totally contradict expectations are the Acadian flycatcher, red-eyed vireo, northern parula, scarlet tanager, and summer tanager in North Carolina, and the yellow-throated vireo, blue-gray gnatcatcher, yellow-throated warbler, black-and-white warbler, prothonotary warbler, worm-eating warbler, Swainson's warbler, Louisiana waterthrush, ovenbird, American redstart, and Kentucky warbler, in both North and South Carolina (see website on Breeding Bird Survey results for each species, especially refer to trend maps: http://www.mbr-pwrc.usgs.gov/bbs/

htm96/trn626/all.html). Only the populations of two species, the wood thrush and hooded warbler, typically associated with mature forest wetlands do not fit this pattern.

Migratory bird use of remaining forested wetlands should be watched closely. Monitoring should focus particularly on swallow-tailed kite, cerulean warbler, and Swainson's warbler, which serve as umbrella species in many forested wetland areas across the South.

In the Mississippi Alluvial Plain, thousands of acres have been reforested in recent years, due to efforts associated with carbon sequestration. When such treatments are contemplated, effects on wildlife should be considered. Pashley and Barrow (1993) provide guidance on managing wildlife in forested wetlands.

Habitat content (composition and structure) issues: wildlife associated with natural pine forests—Populations of many resident and temperate migratory birds associated with open pine stands are undergoing consistent long-term declines across much of their ranges (Hunter and others 1994, 2001, in press). Many other species of pine associated animals and plants associated with natural stands also are vulnerable. The reason for vulnerability is conversion of natural pine to other forest types and to other land uses.

Harvesting the products of southern pine forests remains a very important part of the southern economy, but the pine forests of today's South are very different from the forests found by European colonists and harvested for naval stores and building materials in the 19th century. Since 1952, extent of natural pine stands in the South has declined from about 70 million acres to less than 35 million acres (chapter 16). The natural pine stands being lost include those dominated by longleaf, pond, and shortleaf pines in the lowland physiographic areas and shortleaf, pitch, and Table Mountain pines in uplands [for the latter see section "Habitat content (composition and structure) issues: migratory birds in upland hardwood forests in interior physiographic areas"]. Natural stands of slash, loblolly, and sand pine are also declining, but densely stocked pine plantations are composed mostly of these three species.

The loss of most of the longleaf pine ecosystem has placed many wildlife species at risk in the Southeast (Abrahamson and Harnett 1990, Marion 1993, Stout and Ware and others 1993). At the time of European colonization, longleaf forests covered an estimated 92 million acres stretching from North Carolina to Texas, interrupted only by major floodplain forested wetlands and occasional prairies (Frost 1993, Landers and others 1995). By the 1930s most longleaf pine had been cutover at least once. About two-thirds of former longleaf pine acreage is now occupied by other pine species or has been converted to other land uses (Croker 1987, Walker 1991).

Less than 3 million acres of the original longleaf ecosystem remain. The total is considerably less if systems drastically altered by fire suppression are excluded (see chapter 16). The loss of all but a little of the longleaf pine ecosystem has led to the rarity or endangerment of at least 70 plant taxa, particularly on the Coastal Plain and Florida Peninsula but also on the southern Piedmont and other physiographic areas in the Southeast (Noss and others 1995). Among vertebrate animals, the future of the flatwoods salamander, gopher frog, indigo snake, gopher tortoise, coastal plain fox squirrel, and many other species may well depend on reinstituting growing season fire and restoring the longleaf pine ecosystems.

The loss of fire-maintained shortleaf pine communities is also placing many species at risk (Hedrick and others 1998, Wilson and others 1995). Fire-maintained pond pine stands in North Carolina pocosins also places many species at risk (Moler and Franz 1987, Richardson and Gibbons 1993). Sparse stands of sand pine are particularly important component of threatened or endangered Florida scrub communities (Myers 1990). Natural loblolly pine associated with forested wetland communities on bluffs and ridges in floodplains can provide important nest sites for species like swallow-tailed kites and bald eagles. Finally, the loss of fire as a management tool in the Appalachians has led to extirpation of many species and called into question the future of endemic Table Mountain pine communities (Buckner and Turrill 1999, Williams 1998).

Although a large number of species depend on mature southern pine forests, most attention has been focused on one species, the red-cockaded woodpecker. The red-cockaded woodpecker will recover only where large patches of mature pines are managed for the special foraging and nesting habits of this species (U.S. Fish and Wildlife Service 2000). Other species that may be found in shrub-scrub,
but optimally use sparsely stocked pine savanna and open pine stands include northern bobwhites, Bachman's sparrows and Henslow's sparrows (winter only). Southeastern American kestrels, red-cockaded woodpeckers, and brown-headed nuthatches may be found if longleaf or slash pines are old enough for cavities.

Cooperating private landowners in the North Carolina sandhills and in areas supporting quail plantations in southwestern Georgia play crucial roles in maintaining relatively healthy (and likely recoverable) red-cockaded woodpecker populations. In these cases, timber production is not necessarily the highest priority land use. Cooperative relationships are also being developed with private landowners who manage mature southern pines for timber production. Such relationships require much care and compromise from all parties. Many stands of mature southern pines (including longleaf) may have been cut and converted to other tree species or land uses earlier than originally planned by landowners who feared government regulations to restore red-cockaded woodpecker populations.

Habitat content (composition and structure) issues: migratory birds in upland hardwood forests in interior physiographic areas—Migratory bird declines in the interior South, especially in largely forested areas, may be due to the way much of the forest cover increase has come about. On public land, management has been largely passive since the massive cutting prior to Federal purchase in the 1930s. Much private land has been repeatedly high-graded, with no or little attention to future stand structure or composition. Both of these approaches to managing forests differ markedly from the intensive short-rotation, even-aged management in the lowland physiographic areas. Unfortunately, passive management and high-grading both have led to a lack of structural diversity in mature forests and a serious lack of early seral habitat for many vulnerable species.

Where a combination of even-aged and uneven-aged regeneration strategies is employed, there is increasing evidence that silviculture conducted in largely forested landscapes provides benefits not only to species requiring early successional stages, but also to a surprising number of species requiring mature forests (Annand and Thompson 1997, Bourque and Villard 2001, Pagen and others 2000, Powell and others 2000, Thompson and others 1992). Several studies have documented the importance of early successional forested habitat for providing food and cover for post-breeding and transient juvenile and adult migratory birds (Anders and others 1998; Kilgo and others 1999; Pagen and others 2000; Perry and others 2000; Suthers and others 2000; Vega Rivera and others 1998, 1999).

Some effects of disturbance frequency on general composition and structure are worth summarizing here. In the South, forests that are the least disturbed by fire and storms are in the protected coves of the Appalachians, principally Cumberland Mountains and southern Blue Ridge. Here, mixed mesophytic forests dominate and the few virgin stands that remain, such as those in the Great Smoky Mountains National Park, match up with expectations of what old-growth forests should look like. Also in the Appalachians, spruce-fir-northern hardwood and hemlock-white pine stands once established have developed over centuries with minimal disturbance. Other relatively undisturbed forests include mixed-mesic forests on the Coastal Plain, such as those on the Apalachicola Bluffs. They also include many types of forested wetlands that are removed from frequent natural floods.

When disturbances occur in today's highly altered forests, the effects differ from what would have been expected prior to European settlement. Presumably, storms of moderate intensity caused gaps in uneven-aged, multi-layered forest stands. Densely stocked stands associated with even-aged or heavily high-graded stands are typically resistant to moderate storm intensity. Extreme storms are likely to cause reinitiation of old-growth stands in a more-or-less even-aged state. They also cause younger even-aged stands to be replaced by new even-aged stands. Autogenic regeneration events are largely missing from today's even-aged or high-graded southern forests. This lack of storm-driven autogenic regeneration in midsuccessional or high-graded forest influences habitats for birds and other wildlife (Hunter and others 2001). A difference between even-aged and high-graded stands is that the former can be converted into more vertically structured stands through prescriptions. In most instances, the only option for diversifying high-graded stands is to first clearcut (i.e., start over) and have in prescription intermediate procedures intended to develop vertical stand diversity over time.

The overall lack of forest structure in many of today's forests may explain why so many bird species respond positively to timber management practices in largely forested areas. Heavy and successful use of clearcuts and forest edges by "forest-interior" or "area-sensitive" species in largely forested regions appears to be a response to the poor structure of extensive forests away from treated areas. Clearly, more research is needed on this topic. Composition also contributes to habitat quality. Forest composition is constantly changing and should be a primary consideration in largely forested regions in the interior physiographic areas. Serious issues related to composition include: (1) the active conversion of hardwoods to pine; (2) the passive conversion through fire suppression of naturally occurring southern pine stands to hardwoods; (3) the conversion, again due to fire suppression, of oak com-munities to either mesic hardwoods or white pine; (4) loss of southern Blue Ridge spruce forests; and (5) loss of naturally occurring open habitats such as glades, barrens, balds, bogs and fens.

At one end of the management-intensity spectrum are the passive management strategies now most prevalent on public land. These strategies are causing major changes in forest composition and forest biotic diversity. Passive management is causing abnormally heavy stocking, and fire suppression is causing vulnerable mountain yellow-pine communities (principally Table Mountain and pitch, but also shortleaf and longleaf) to succeed into hardwood communities (Buckner and Turrill 1999, Delcourt and Delcourt 1997). Recent southern pine beetle epidemics have all but eliminated these already vulnerable communities from many areas in the Appalachians. Similarly, oak-hickory stands are being invaded by more mesic hardwood species and white pine. These invasions of more mesic adapted species into more fire-prone conditions may lead to extremely high fuel loads during dry years. In the long run, severe and catastrophic fires will result. Catastrophic fires can further alter forest habitat conditions so that most vulnerable species do not thrive, including disturbance-dependent species in the long-run if these catastrophic events are not soon followed by subsequent prescribed burning to restore appropriate habitat conditions associated with regular fire-return intervals (Delcourt and Delcourt 1997, White and White 1996).

Like other forest types, spruce-fir-northern hardwood forests were harvested near the beginning of the 20th century. The stands that replaced them differ from those prior to harvest. Generally, spruce was replaced by fir from higher elevations and northern hardwoods from below (White 1984). Since a high percentage of the community is in public ownership, it would appear that healthy high-elevation biotic communities can be protected. Fraser fir, however, is threatened by exotic pests, possibly compounded by effects from regional air pollution (Nicholas and others 1999, Rabenold and others 1998, White and others 1993). Some effective restoration probably is possible for red spruce but would require the conversion of existing northern hardwood stands to either spruce or spruce-hardwood mixtures. Some 50,000 acres of such treatment would be needed to reach preharvested forest conditions.

As many as seven forest bird species closely associated with southern spruce-fir-northern hardwood high-peaks forests are effectively isolated from more northerly and western populations. Among these species, the northern saw-whet owl appears to be the most vulnerable to potential habitat loss (Milling and others 1998, Simpson 1992), followed by the black-capped chickadee and the red crossbill. Although widespread elsewhere, the owl and other species restricted to high-peaks forests for breeding in the Southeast need relatively high levels of conservation attention. Northern saw-whet owls respond to nest boxes, which may partially mitigate the loss of high-elevation conifers. Owls also may use other habitat, such as older northern hardwoods and hemlock (Milling and others 1998).

Habitat content (composition and structure) issues: summary assessment of wildlife use of pine plantations—Acreage of pine plantations has increased from 2 million acres in 1952 to 30 million acres today, and an additional 25 million are expected in the foreseeable future. Not surprisingly, the conservation community worries about possible effects on the future sustainability of naturally occurring forests in the South. Although a large percentage of this increase and projected increase comes from retirement of agriculture land (see chapters 16 and 6), there is also a substantial loss of natural pine communities. The loss of natural pine acreage is as much due to fire suppression and clearing for agriculture and urbanization as to conversion to plantation pine. In fact, pine plantations that are invaded by hardwoods often become indistinguishable from natural stands. On many millions of acres, fire suppression since the 1950s has allowed former pine stands to now be classified as pine-oak or even upland hardwood forest types (see chapter 16). So there is no direct correlation between loss of natural pine acreage and increase of plantation pine.

Still, much natural pine acreage and hardwood acreage (both bottomland and upland) have been converted and devoted to efficient growth of short-rotation pine in the South. Although there is general recognition that intensively managed pine plantations are not high-quality wildlife habitats when compared with natural pine and hardwood forests, statements made in several chapters of this report suggest overall that such intensification of management is a positive trend (see chapter 14). Certainly, afforestation of millions of acres of farmland provides for many benefits, from carbon sequestration to water quality improvements. Greater intensity of forest management may allow other forested acres to be set-aside for other purposes, such as wildlife and recreation. However, that intensive forest management actually allows other forest lands to be set-aside or managed for other values, such as wildlife, requires greater scrutiny.

How forests not needed for timber production will be used is unclear at best. Land use trends support that many acres of forest land will be developed, regardless of their productivity. There is no indication that funds would be available to support management of forest lands for wildlife short of commercially viable procedures. Over the last 100 years, many millions of acres of pine and hardwood forests have been left in poor condition for many species of wildlife, including both game and nongame species. Even claims that the present and projected increase in intensively managed pine plantations should bode well for early successional species is highly suspect. High stocking rates (700 to 1000 seedlings per acre), increasing use of fertilizers and herbicides for maximizing pine growth, and reduction of fire as a management tool, among other management changes, essentially have eliminated many of the benefits for early successional species of wildlife that were provided formerly in pine plantations that were less efficiently managed. There certainly is no evidence that steep population declines have been halted or reversed with the expansion of intensively managed pine plantations during the last 30 years. Declining trends continue for important species like northern bobwhite, American woodcock, and many species of high-priority nongame migratory birds associated with early successional habitats (Capel and others 1994, Hunter and others 2001, Krementz and Jackson 1999).

Another major issue in the South is the proliferation of chip mills during the last decade. An important background point is that the chip mills were established in many areas because of poor forest conditions created by repeated past "high-grading"—selective removal of the biggest and best formed trees in hardwood forests. What remains is an unhealthy forest that is poor wildlife habitat. In many of these areas, clearcutting for pulpwood is the first step toward improvement, and chip mills make clearcutting feasible. However, when these hardwood acres are replaced with densely stocked pine plantations, wildlife will not benefit for very long. The alternative often promoted as "environmentally friendly forestry" involves diameter-limit cutting for sawtimber. Diameter-limit cutting, in essence, is a form of high-grading, which was the dominant practice that led to the low-quality hardwood stands found in much of the South.

Management of pine for pulpwood and/or sawtimber need not be as bad for wildlife as is often portrayed. Effects on wildlife involve many factors, including landowner objectives, site quality, and options available for implementing management practices (Melchiors and others, in press). For example, planted loblolly pines in pocosins usually replace stands dominated by pond pine, Atlantic white-cedar, or bays. After pines are established, a manager could provide suitable habitat for many neotropical migrants by retaining a dense hardwood understory and midstory. Reduction in growth and quality of overstory pines would be relatively small.

Notably, nearly all of the forested wetlands lost in coastal North Carolina, much of which was pocosin, were converted to nonwetland uses, including pine plantations (Hefner and others 1995). Although concern for the future of remaining pocosin communities is justified, there is evidence that converting "natural" pocosin vegetation to loblolly pine can have neutral to positive effects on some of the vulnerable neotropical migrants. Neotropical migrant use of these pocosins converted to pine plantation is best when hardwoods are encouraged in the understory and midstory through precommercial and commercial thinnings and infrequent burning (Karriker 1993). Among the species appearing to be stable in these commercial forests are yellow-billed cuckoos, Acadian flycatchers, worm-eating warblers, ovenbirds, and prairie warblers. However, loblolly stands managed for sawtimber under these treatments are still less than 20 years old and have yet to show consistent use by the three highest priority species: black-throated green, Swainson's, and prothonotary warblers. These species require large patches of tall pocosins and other forested wetlands along the South Atlantic Coastal Plain. Optimum management of high-priority, nongame landbirds in pine plantations would include retention of some patches of "natural" pocosin vegetation or otherwise encouraging hardwood understory or midstory development. Conversion from hardwoods to pine or pine-hardwood mix, with appropriate management, is clearly better than no forested habitat at all. For many high-priority neotropical migrants in these habitats, however, restoration and appropriate management of forested wetland conditions would be even better.

The hypothesis that forested wetland species are making the transition to using "bedded" pine plantations is supported by studies in North and South Carolina: (1) in the Parker Tract, Weyerhaeuser Company, NC (Kerriker 1993, Wilson and Watts 1999a); (2) in the Woodbury Tract-Pee Dee River, International Paper Company, SC {Lancia and Gerwin [In press (a)]}; Mitchell and others 1999); and (3) in the ACE Basin, Westvaco Corporation, SC {Lancia and Gerwin [In press (b)]}. The latter two study areas are also the subject of a landscape-level analysis in Mitchell and others (2001). Preliminary results from these studies are promising but long-term benefits depend on maintaining substantial hardwood understories with certain structural characteristics. Heavy bird use of existing woodlands may be temporary as forest management becomes more intensive and hardwood types are replaced by pine. Regardless of the reasons, birds usually associated with hardwood forests are making substantial use of pine plantations in the Coastal Plain of the Carolinas, at least for now.

In the Ouachita Mountains, the USDA Forest Service and Weyerhauser Company, among other partners, have embarked on a watershed comparison among passively managed, moderately managed, and intensively managed sites. Preliminary results suggest that large areas under active management likely support a variety of habitat conditions at a variety of spatial scales suitable for many bird species, including many high-priority species associated with both mature forest and early successional conditions (Melchiors and others, in press). The more actively a large area is managed, the more heterogeneous the available habitat, and the less actively managed, the more homogenous the habitat. The latter support surprisingly few mature forest species in numbers higher than those found in more actively managed watersheds (Melchiors and others, in press). In contrast to the Carolina studies, where reproductive rates appear to be consistently high, studies from the Ouachita Mountains and Georgia Piedmont have revealed more complex patterns of nesting success that depend on seral stage, burning regime, and percent canopy versus understory cover (Barber and others 2001, Brunjes 1998, Howell 1998, Raftovich 1998). In addition, heavy and apparently successful use of pine habitats in the Carolinas and possibly elsewhere are generally where sawtimber is the target wood product, where sites have the propensity to support substantial hardwood growth or where maintenance of interspersed hardwood stands are maintained as "ecological legacies." Data are not available to suggest the same is true for the vast majority of pine plantations, which are managed in very short rotations on very well-drained sites with dense stocking and heavy chemical use.

In conclusion, management options exist in some locations to support healthy migratory bird populations. Study results, however, do not cover the vast majority of pine plantations and how they are managed in the Southeast. Regardless of whether some hardwood species persist in some pine plantations, priority bird species associated with older pine stands are probably harmed the most by the expansion of pine plantations. Plantation pine stands are too dense, too young, or hardwoods in their understories are too dense for the bird species usually associated with open pine stands that are frequently subjected to prescribed or natural fire. Some of these species may persist in managed pine plantations where hardwood intrusion is controlled and snags are retained (Caine and Marion 1991; Dickson and others 1983; Land and others 1989; Moorman and others 1999; Wilson and Watts 1999a, 1999b,).

For nonavian wildlife, results of studies are also mixed, but similar themes emerge for small mammals and reptiles as found for birds. Working in plantations over former pocosins in eastern North Carolina, Mitchell and others (1995) found that small mammals undergo an initial decline, but later recover to preconversion population levels as long as the plantation emulates, to some degree, the understory structure of the former pocosin. Stand thinning and growing-season burning are essential for maintaining gopher tortoise populations in slash pine plantations in southern Alabama (Aresco and Guyer 1999). Longleaf pines with cavities retained in mature park-like pine plantations in the upper Coastal Plain of South Carolina were used for evening bat roost sites and seemed preferred to potential sites in dense canopied bottomland hardwood, mixed pine-hardwood, or loblolly stands (Menzel and others 2001).

Pine plantations are generally poor wildlife habitat. However, with management adjustments (from less intensive to maintaining natural community types mixed in with plantations) many vulnerable wildlife species can successfully use these commercially driven habitat conditions. At the very least, pine plantations may provide buffers around more natural forested habitats that are clearly better than agriculture or urban areas for hardwood associated songbirds (Kilgo and others 1997, 1998)

General management considerations—Any major change in a forest affects the wildlife that live there. Some changes are caused by purposeful management actions. Others are the result of natural processes (Dickson and others 1993). Managers prescribe treatments to enhance the production of various resources or to promote a forest condition, such as habitat for a particular wildlife species or the quality of a scenic vista.

Different wildlife species and populations react differently to habitat manipulations. Some species are habitat generalists, which have the ability to survive in a wide variety of conditions. Others are habitat specialists, which require specific conditions in order to maintain viable populations. These species have evolved over time to capitalize on unique habitat niches.

An example of a bird habitat specialist is the prothonotary warbler, which needs small cavities in midstory trees or shrubs to successfully nest. Other examples of birds that are habitat specialists include cerulean warblers, Swainson's warblers, and red-cockaded woodpeckers. Habitat generalists, on the other hand, can survive and successfully reproduce in a wide variety of conditions. Examples of habitat generalists include white-tailed deer, raccoons, and coyotes.

Wildlife species also differ widely in mobility. Large vertebrates and birds generally have large home ranges. Black bears have been known to travel over 300 miles, and many birds travel between continents. Many amphibian species, on the other hand, spend their entire lives near the place they were born. Therefore, consequences of changing habitat conditions vary widely among wildlife species.

Timing and energy requirements are extremely important for migratory birds. Favorable weather conditions and adequate food are critical to sustain populations. In the context of forest management, providing as much high-quality habitat as possible is critical. Often, due to localized climatic factors, lands on which migratory species depend are less than optimal. Waterfowl, particularly ducks, are often affected by localized drought, failed seed crops, or extended freezes. When these events take place, it is critical that areas outside of preferred migratory routes provide missing elements. Even though most migratory waterfowl breed in the northern portions of this continent, pair bonding occurs on the wintering grounds. Reproductive success and survival, therefore, depend on the quality and quantity of habitat along the entire flyway, including southern forested wetlands.

Stand-Level Management

In forestry and wildlife management, the primary management unit is the stand. Stands are analogous to plant communities, but there are differences. Boundaries and sizes of natural plant communities are dictated by topography, soils, hydrology, and past history, whereas stands are delineated by human-induced disturbances. Stands are the basic land units on which specific silvicultural treatments take place. On a landscape scale, the arrangement of stands and the implementation of treatments, both spatially and temporally, have a great affect on wildlife.

In a simplified model, if management objectives are to provide a mosaic of even-aged habitats, with stands of all ages represented, land managers may arrange operations so that similar habitats are scattered across the landscape. As a result, habitat requirements of a variety of wildlife species are met locally.

Forest stands are dynamic, moving along a successionary continuum and providing different benefits at different times. In all cases, forest communities are created and maintained by disturbance and succession, whether they are natural or management induced (Oliver 1981).

Ecological Basis of Silviculture

Silviculture is the ecological art and science of managing forest stands to meet landowner objectives. It is also the applied ecology portion of forest management. Forest management considers the entire forest, which is made up of numerous stands; while silviculture deals with individual stands. Landowner objectives may include timber management, wildlife management, aesthetics, and recreational opportunities.

Silviculture is based on two basic ecological patterns. The first is succession, or the way forest communities develop over time. The second is disturbance, or an event that destroys all or part of an existing forest community. These patterns are natural phenomena in all forest types and take place on many different scales. Succession and disturbance are related because succession cannot be altered without disturbance. Plant communities develop through succession and are altered through disturbance. In a natural situation, succession and disturbance are chaotic. Disturbance events are unpredictable, both spatially and temporally.

Even though silviculture is based on natural processes, it does not precisely mimic them. Through the use of silvicultural techniques, natural processes are allowed to take place to produce desired conditions. An understanding of the underlying ecological principles is essential in comprehending silviculture and forest management.

Succession—Succession may follow two basic patterns, primary succession or secondary succession. These two basic types of succession are addressed in more detail later in this chapter. Silviculture most often mimics secondary succession, since some plant community generally occupied the site before it was subjected to disturbance. In order for succession to begin, some sort of disturbance has to take place. After the disturbance, new plants invade the site and begin to grow. Succession is accurately described as occurring along a time continuum, starting with year zero and continuing until another major disturbance. Left to their own devices, forest stands go through four distinct stages of development: stand initiation, stem exclusion, understory reinitiation, and steady state (Oliver and Larson 1990).

Succession: stand initiation—The first successionary stage is stand initiation. During this stage, water, nutrients, and sunlight are plentiful due to the lack of existing vegetation. In the South, plants quickly occupy the site and begin to compete for available resources. Herbaceous plants seed in and existing rootstocks sprout. Plant diversity is high relative to midsuccessional stages, since species with varying levels of shade tolerance all occupy the site simultaneously. Plants that reproduce from rootstocks and plants that are shade intolerant have a competitive advantage during stand initiation.

Succession: stem exclusion—As a stand matures, resource limitations occur. On upland sites, either water or nutrients may be in short supply. On bottomland sites, sunlight is usually the limiting factor. When available resources begin to limit the growth and establishment of new plants, the stand is in the stem exclusion stage. At this point on the successionary continuum, shade-intolerant understory species begin to disappear; and the plant community becomes dominated by trees. Fast-growing, shade-intolerant tree species generally overtop competing vegetation, and competition for available resources is extreme. Shade-tolerant species usually have slower growth rates and tend to lag behind. As this stage progresses, stratification occurs, usually resulting in a well-defined midstory and overstory.

Succession: understory reinitiation—Shade-intolerant tree species are usually replaced in the overstory by midtolerant species during the understory reinitiation stage. As shade-intolerant species reach full height, other species begin to out-compete them for available resources. Gap-phase dynamics begins to occur during this stage. Trees, or groups of trees, die for many reasons and are replaced either by trees that are presently in the midstory or by new reproduction. The forest canopy begins to become more heterogeneous, allowing sunlight to penetrate from above and from the sides. As trees die, resources are allocated to remaining individuals, many of which respond with increased canopy growth and diameter growth. With increased sunlight reaching the forest floor, herbaceous plants become established and flourish. Depending on forest type, species composition may shift, with shade-intolerant species giving way to more shade-tolerant ones.

Succession: steady state—The steady-state stage of succession is anything but steady, but it does tend to perpetuate itself to some extent. In many southern forest types, this stage exists only in varying degrees, with fire (historically) being the major contributing factor in arresting or setting back succession. This stage is a continuation of the understory reinitiation stage and is marked by small-scale disturbances that contribute to gap-phase dynamics. As gaps continue to form and develop over time, structure and species composition become quite complex. The presence of many gaps in various stages of development creates stand conditions where trees of many ages, sizes, and species exist simultaneously. In many systems, mature trees on the edge of gaps are more susceptible to mortality due to increased exposure, creating an expanding gap pattern of development over time.

Disturbance—Disturbances vary in severity, frequency of occurrence, and predictability. Generally, certain types of disturbance are more common in particular forest types. Low-intensity ground fires were common in southern pinelands and were characterized by high frequency and low severity. Windthrow during storms is a common disturbance in bottomland hardwood forests where trees have shallow root systems in moist soils.

An inverse relationship also usually exists between severity and frequency of disturbance. Frequent, low-intensity disturbances usually affect only part of the plant community. Low-intensity groundfires in pine stands detrimentally impact hardwood midstory and understory species but do not harm the pines in the overstory. In bottomland hardwoods, however, fires are infrequent and may potentially set entire stands back to the stand initiation stage.

Silvicultural Systems

Natural regeneration: uneven-aged silviculture—Uneven-aged management has been used successfully in several southern forest types. In this type of management, trees of several age classes are present in the stand at all times. Stands are usually regulated by volume and managed to maintain a specific diameter distribution, with many smaller trees and fewer large trees. Since most commercially desirable tree species in the South are relatively shade intolerant, the upper canopy must be reduced such that younger trees are able to grow into the overstory.

This type of management has many benefits for wildlife, especially birds. Due to high levels of canopy stratification, many bird species are able to utilize these stands (Dickson and others 1995). Different bird species rely on different portions of the canopy. Wood thrushes require dense understory growth, while cerulean warblers utilize emergents, which are individual trees that are taller than the main canopy. With respect to emergents, it has been demonstrated that canopy height is not as important as relative height. In most uneven-aged stands, larger trees act as emergents due to their size relative to their immediate neighbors.

Uneven-aged management of both pines and hardwoods requires frequent entry into the stand, increasing risks of disturbing wildlife and rutting or compacting the soil. More access roads are also generally required for this type of management, and they must constantly be open. In uneven-aged pine management in particular, increased herbicide use is often required to release pines from more shade-tolerant hardwood competition (Dickson and others 1993).

Area regulation in uneven-aged management has become an accepted method for managing both pines and hardwoods, especially when wildlife enhancement is the primary objective. Area regulation differs from volume regulation in that equal areas of land within a stand are harvested at each entry, rather than cutting the stand to a specific diameter distribution. Area regulation has been used with great success in longleaf pine and bottomland hardwoods, where large, homogeneous stands exist. In bottomland hardwoods, waterfowl habitat is enhanced, particularly in areas where foraging and pair bonding occur.

Natural regeneration: even-aged silviculture—Even-aged management is very common in the South. It lends itself well to southern ecosystems mainly because most of the commercially desirable tree species are shade intolerant. In even-aged management, only one or two age classes of trees are present in a stand.

A clearcut is the most basic technique for initiating an even-aged stand. In the following paragraphs, clearcutting with natural regeneration is addressed. Artificial regeneration will be discussed in the narrative on plantations. In clearcutting, the entire stand is removed in one harvesting operation, and a new stand of trees takes its place. Clearcut areas may be regenerated naturally from sprout reproduction, from seeds from surrounding stands, or from seeds that were in place before mature trees were removed. Hardwood stands often are regenerated with advance reproduction, which was in place before the initial harvest (Baker 1997, Hodges 1997).

From a wildlife management perspective, clearcuts have the benefit of providing maximum amounts of light reaching the ground, which improves growth of herbaceous plants (Pietz and others 1999). Many wildlife species thrive in early successional communities created by clearcutting (Wigley and others 2000). The possibility of erosion may discourage clearcutting on sites with steep slopes. In wet areas, clearcutting may raise the water table excessively because transpiration is greatly reduced by removing most plants. If the water table rises to the soil surface, establishment of a new stand may be impeded.

Seed trees were often used for regeneration in the South until about 15 years ago. This approach is losing favor to clearcutting and planting, which allows introduction of genetically improved stock. In the seed-tree method, four to eight mature trees per acre are left to provide seeds for regeneration. After the stand is regenerated, the seed trees are removed. From a wildlife management perspective, this technique provides the benefits of large amounts of light reaching the ground, while some structural elements are retained for several years after harvest (Dickson and others 1995). In some cases, seed trees are left on the site, rather than being removed.

Regeneration by the shelterwood method is common with tree species that regenerate best in partial shade. Heavy-seeded species are generally not regenerated with either seed-tree or shelterwood techniques. Shelterwood cuts are attractive to neotropical migratory bird species that are associated with either early- or late-successional stages (Dickson and others 1995). Shelterwood cuts in overcup oak stands in green-tree reservoirs have also been successful. Overcup oak acorns are disseminated widely by water, and the reduction in canopy density attracts macroinvertebrates, which are important food items for waterfowl.

In both seed-tree and shelterwood regeneration techniques, a second and sometimes third entry is made into the stand to remove remaining trees. In shelterwoods, entry is usually essential to release reproduction. Irregular shelterwoods may retain "leave trees," which are mature trees left in the stand to provide structural diversity, wildlife habitat, or seed sources. Management of two-aged stands is becoming popular on public lands and initial evidence is that with respect to forest birds, this may be an acceptable option to clearcutting (Duguay and others 2001).

Natural regeneration: intermediate treatments—Thinning is a common silvicultural technique used to concentrate growth on fewer trees. Stands are commonly thinned during the stem exclusion stage and are sometimes thinned again later in the rotation. Thinning temporarily reduces canopy coverage and allows light to reach the forest floor, promoting growth of understory plants. Thinning may also temporarily create canopy complexity, which is positive for many bird species (Dickson and others 1995, Wigley and others 2000).

Timber stand improvement (TSI) cuts are used to remove trees that are less desirable because of their species, form, or health. Although these cuts allow sunlight into the stand, in many cases they remove individual trees that are beneficial to wildlife due to their form or the presence of cavities.

Herbicide use has become extremely common in forest management. Historically, prescribed fire was used to remove unwanted vegetation. Herbicide treatments have taken the place of prescribed fire in many areas. Herbicides may be sprayed from the air or from the ground, injected into unwanted stems, or squirted onto wounds hacked through the bark. Such treatments are very effective in reducing competition and promoting crop-tree growth. Most herbicides labeled for forestry use today have extremely low vertebrate toxicity and are not immediately detrimental to wildlife. Negative impacts of herbicides usually are associated with decreases in plant diversity, but herbicides can be positive for wildlife under specific circumstances and especially where prescribed fire is no longer a viable management option (Wigley and others 2002).

Other than reducing competition, herbicides are also used to change stand structure. Individual stems in hardwood stands are commonly treated to reduce shade-tolerant species and allow space for advance reproduction (Hodges 1997). Trees treated with herbicides create snags and downed wood, which are beneficial to some wildlife species. Overstory trees are sometimes treated chemically to allow sunlight penetration, creating large upper canopy snags. Although they are beneficial to a variety of wildlife species, canopy snags usually remain standing for only a few years in the South (Dickson and others 1995).

Fertilizer application is increasingly common in southern forests. Both pine and hardwood stands are treated to increase crop-tree growth, but the practice is almost totally restricted to pine plantations. Productivity of forest sites is increased by applying nitrogen, often in combination with phosphorous (Lauer and Zutter 2001). Fertilizers are generally applied at the time of establishment and again at midrotation.

Fertilization produces several wildlife benefits. Most plant species on the site respond to increased nutrient levels, creating more browse and more fruit production. These effects, however, are usually short-lived, because stands generally reach canopy closure sooner with fertilizers than without. Responses usually last only two to three growing seasons (Dickson and others 1995).

Plantation management—Forest plantations are not all created equal. They take many forms, depending on intensity of management, species being managed, and site. Like any other plant community, a plantation is affected by hydrology, topography, and climate. Plantations range from loblolly pine plantings on old fields to hardwood fiber farms that are irrigated and fertilized. Well-managed plantations on good sites often produce vastly greater yields than natural stands. Operations in these stands are straightforward and relatively easy. Although plantations produce wood rapidly, the ecological consequences, described below, can be very large.

Plantation management: ecological consequences of plantation management—Plantations established on clearcuts retain biological legacies from the old stand in the form of seed left in place and rootstocks that have the potential to sprout. Plantations established on old pastures or agricultural fields tend to contain mainly pioneer species. Ecologically, plantations established after timber harvests tend to mimic secondary succession, while those established on old fields are more similar to primary succession. In the Mississippi Alluvial Valley, stands originating on abandoned agricultural fields contain plant communities similar to those originating from primary succession on river bars (Baker 1997). Similarly, cottonwood plantations tend to have species composition similar to natural cottonwood stands of river front origin.

Natural primary succession tends to establish stands of a single species. In a landscape mosaic, these stands provide many positive values for wildlife. These stands are usually short-lived and provide structure, cover, and food for a variety of wildlife species. On heavy clay sites that are frequently flooded, pure black willow stands provide many benefits for waterfowl. Invertebrate production is great, cover is dense, nest cavity formation is high, and temperature fluctuations are moderated. Investigators have demonstrated that ambient winter temperature is higher in black willow stands than elsewhere. As these stands break up naturally, longer-lived species take their place, providing structural components that are favorable for many migratory bird species. These stands grow rapidly during stand initiation, providing vertical structure sufficient for bird use within 2 to 5 years. Birds are a major dispersal mechanism for oaks (Hodges 1997), and as bird use increases in new stands due to increased vertical structure, oaks seed dispersal is increased.

In the South, primary succession takes place when new land is formed by river movement. In other parts of the world, it may take place after volcanic or glacial activity. Primary succession does not generally occur on sites where pine plantation establishment is the main objective. Although forest monotypes occur naturally in the South, they are restricted to hardwood species along river and stream corridors. On upland sites, where these situations exist, they must be artificially created and maintained. Even in instances where severe fires have taken place in the uplands, biological legacies still exist and no new lands have formed.

Wildlife species that thrive in early successional habitats use plantations heavily during the first few years after planting (Wigley and others 2000). Browse is abundant and species such as white-tailed deer, eastern cottontails, and black bears frequent young plantations. Small mammals also use these areas heavily; consequently, raptor use is high. Several neotropical migratory bird species use plantations early on, when insects and seeds are abundant. After canopy closure takes place, plant diversity decreases and wildlife use declines.

When plantations are first established on previously forested sites, water, nutrients, and sunlight are plentiful, supporting diverse and abundant plant communities. Even though sites are mechanically prepared and competing vegetation is usually controlled with herbicides, other plant species are still able to survive. Many wildlife species benefit from the grasses and forbs that are present on these sites during stand initiation. As the planted crop trees mature, they shade out competing vegetation, reducing plant diversity and structural complexity. As a result, soft mast, browse, and cover are reduced. Subsequently, fewer wildlife species find these sites suitable after canopy closure.

Plantation management: common plantation practices—Loblolly pine is the most common plantation-grown species in the South. Its wood has desirable properties, it grows rapidly, and it is easy to establish. That is why it is the species of choice over much of the Southeastern United States. Slash pine is also a common species for plantation management. It is similar to loblolly pine in most characteristics, and cultural practices are also similar.

Plantations may be established in a variety of ways, but they all begin with some form of site preparation. Site preparation may be as simple as removing the old stand from the site, or as intensive as chopping, windrowing, burning, ripping, bedding, and fertilizing. Site-preparation treatments are designed to give the crop trees a competitive advantage over competing vegetation. On the Coastal Plains and Piedmont, ripping and bedding are common practices, despite high costs. Seedling survival is enhanced with these practices, as is rapid early growth of planted stock. Herbicides are commonly used when sites are ripped and bedded, and are effective in reducing competition.

In managed pine plantations, positive aspects for some wildlife species are gains in vertical structure in a short time period and rapid provision of cover. Negative aspects are reductions in time until canopy closure and subsequent shading of competing vegetation (Dickson and others 1995, Wigley and others 2000). In plantings on clearcut sites, downed wood is usually abundant and in some cases snags are left. Snags left standing may present a danger to loggers, but they provide great benefits to cavity-nesting wildlife species.

Pruning is common in the West Gulf region, where production of high-quality products like poles or lumber is the goal. Many plantations are pruned to produce clear, knot-free wood on the bole in a shorter period of time than without pruning. Pruning is usually done after a thinning and has the potential to positively impact many wildlife species. It has the potential to increase canopy complexity and increase understory vegetative growth. It also increases amounts of dead wood on the forest floor, providing habitat for small mammals and increasing organic carbon levels in the soil. Use of these stands by some hawks and owls may be increased due to greater visibility and increased numbers of small mammals.

Bird use in young plantations is generally high until the canopy closes about 10 to 12 years after establishment. Use declines because there is no canopy stratification and understory vegetation decreases. Leaving mature trees in the stand creates a structural element that has the potential to greatly increase bird use, but the residuals slow the growth of crop trees where shading occurs. Structural diversity is created in the stand on two levels (Dickson and others 1995).

Wildlife Management Techniques

Active wildlife management in southern forests is very common (Dickson 2001). Substantial economic benefits are available for those willing to lease land for hunting or other recreation. Much industrial timberland in the South is leased for hunting. Game species, such as white-tailed deer, wild turkeys, bobwhite quail, and waterfowl, are primary management targets. Entire texts have been written describing practices that enhance game animal populations. This section describes common wildlife management practices in southern forests.

Maintenance of riparian vegetation along streamsides is almost universally considered essential by natural resource managers. It minimizes movement of sediment from upslope areas into streams (National Association of Conservation Districts 1994). In addition to improving stream quality, streamside buffers may benefit many rare and declining aquatic vertebrate and fish species throughout the Southeast. However, of even greater interest are benefits accrued by bird species. Streamside management zones, if widely implemented across a landscape, can support some vulnerable species. Because landbirds are not the sole concern when managing riparian habitat, the most effective conservation will balance economics with the needs of wildlife, including vulnerable neotropical migrants.

Streamside management zones (SMZ) are strips of various width along streams that are not managed like the rest of the stand. They usually contain mature deciduous trees, and timber management in these corridors either ceases or is scaled back in intensity. The primary function of SMZs is to provide a protective buffer that decreases logging impacts on streams, but SMZs also create structural diversity in stands. Wildlife use them for breeding and foraging, and as travel corridors (Machtans and others 1996). Brown-headed cowbirds are a major problem for other bird species in SMZs when the surrounding land has been recently harvested. Cowbirds utilize early successional habitat. During stand initiation after a disturbance, they often reduce nesting success of other species utilizing adjacent SMZs (Dickson and others 1993).

Melchiors (in press) and Wigley and Melchiors (1994) describe management opportunities as well as important caveats for interpreting existing data on wildlife use of retained riparian vegetation in actively managed landscapes. Existing data have been organized into three categories particularly useful for developing management recommendations: (1) streamside management zones in managed (usually short-rotation pine) forest stands, (2) riparian forest habitat in otherwise agricultural or developed landscapes, and (3) moisture/elevation gradients in largely forested landscapes (Melchoirs, in press). Current understanding of bird-habitat relationships in largely forested landscapes, especially in mountainous areas [item (3) above], indicate that forested riparian habitat is indeed important for supporting many species. Managers concerned with the plight of species depending on healthy forested riparian habitat should not place presently stable source populations at risk. Flexibility in managing riparian habitats is enhanced when large landscapes are under cooperative management. Widths of SMZs should be based on the nature of dominant land use patterns. If adjacent land is dominated mostly by mature or maturing stands, narrow SMZs may be adequate. In forests dominated by short-rotation plantation forest management, with many patches of early regeneration present during every decade, wider SMZs probably are needed. Finally, agricultural areas require the widest SMZs if vulnerable landbirds are an important goal for management. In the South Atlantic Coastal Plain, objectives for floodplain forested wetlands should suffice for SMZs.

In most, if not all, Southeastern locations, few important wildlife species would be served by narrow (10 to 25 foot) grassy streamside buffers. Such narrow and grassy riparian conditions may be adequate for minimizing erosion, consistent with the dominant land use. There is little argument among natural resource managers on the importance of maintaining forested riparian areas for wildlife in general, but several points are actively debated. These include: (1) adequate to optimal streamside widths, (2) acceptable structure and plant composition, (3) species to be targeted, and depending on the wildlife targeted, (4) the desired intensity of management consistent with balancing other priority land uses (Wigely and Melchoirs 1994). General guidelines given by Wigley and Melchiors (1994) include the correlation of SMZs with watershed size, the use of narrow SMZs on ephemeral or intermittent streams to promote diversity of bird communities in managed forests, and flexibility in SMZ width.

Costs to maintain wide SMZs can be considerable when timber production is the landowner's only or primary objective. Therefore, financial incentives, conservation easements, and partnerships through public-private programs are critical for stabilizing or enhancing riparian and aquatic habitat throughout the Southeast. Examples include the Farm Bill's Forest Stewardship program and the Partners for Wildlife program. Fortunately, many wood-producing industrial landowners and an increasing number of nonindustrial landowners are maintaining high-quality water and wildlife habitat, especially for landbirds. Nevertheless, recommendations for SMZ width and condition that go beyond State-sanctioned best management practices need to be presented to private landowners as optional treatments.

Cooperating partners should develop joint monitoring efforts in riparian habitats to better understand local responses by vulnerable species to SMZ treatments. Migration monitoring is likely to be most productive in SMZs. Results would add valuable information on timing and degree of transient passage through the South Atlantic Coastal Plain. Efforts to improve watershed management and riparian habitat condition should be monitored by collecting data along tributaries and main streams to the Flint, Chattahoochee, and Apalachicola. All these efforts should involve both public and private groups. Food plots often are claimed to increase game species abundance and health in forest lands that are being managed for hunting. Small areas cleared specifically for planting and woods roads or log landings are generally used. Specific crops planted depend on the site and the species being managed, but peas, winter wheat, ryegrass, and some commercial "wildlife mixes" are generally sown. Keeping small areas cleared has the benefit of creating ecotones, or transitional zones between habitat types, which many wildlife species use. It is debatable, however, whether perpetually cleared areas are as beneficial as those left to natural succession. Food plots may increase the carrying capacity for certain species, but substantial increases usually are not seen. The biggest benefits to hunters and wildlife managers are increases in wildlife observations and subsequent increases in opportunities to harvest game animals.

Green-tree reservoirs are sometimes placed in bottomland hardwood stands to enhance waterfowl habitat. These impoundments are flooded during the winter and early spring and have the potential to greatly benefit waterfowl. Optimally, water levels should fluctuate, increasing foraging potential for dabbling ducks. Hard-mast-producing tree species provide abundant food, and macroinvertebrates are present in great numbers. In addition to waterfowl, potential beneficiaries include reptiles and amphibians that are favored by fluctuating water levels. Warm water fisheries may also be enhanced by green-tree reservoirs. Annual growing-season flooding may decrease regeneration of desired tree species, but dormant-season flooding has little effect on timber quality or growth.

Ecological Variables

Chaotic events—Whatever management options are implemented, it is impossible to accurately predict the onset of natural catastrophic events. Wildlife populations are greatly affected by icestorms, windstorms, blight, southern pine beetles, oak decline, and a plethora of other landscape-altering phenomena. The American chestnut blight basically eradicated a major source of hard mast from the Southern Appalachians, with estimated reductions in hard-mast production of over 34 percent (Diamond and others 2000). Beech bark disease has virtually eliminated American beech from much of its native range. Acid rain has had detrimental effects on red spruce at high elevation in the Appalachians. Recently, southern pine beetle infestations in Kentucky eliminated all suitable habitat for red-cockaded woodpeckers. All of these birds had to be captured and relocated. All of these events have large, long lasting effects on forested ecosystems and the wildlife populations that depend on them.

Landscape altering events have been taking place since the beginning of time. Many have led to species extinctions. In the case of American chestnut, oaks and hickories partially fill the void. Management strategies must be resilient enough to compensate when these events take place.

Soils and topography—Soils are of paramount importance in forest and wildlife management. They dictate, to a large degree, the species assemblages that occupy sites and are directly related to productivity (Hodges 1997). Although no strong correlations exist between site productivity and diversity, sites with highly productive soils tend to be more resilient (Baker 1997).

Silvicultural operations have the potential to impact soils. Harvesting with heavy equipment may compact and rut the soil. The ability of the site to rebound depends on soil type. Wet sites with clays that shrink and swell tend to rebound more rapidly after heavy equipment traffic than more silty soils.

With respect to biodiversity and productivity, little is known about the impacts of converting natural, mixed-species forest stands to pine plantations. In grassland ecosystems, natural prairie sites with high plant diversity are more productive than those with "improved" pastures that contain only a few species. Forests on productive soils with complex structural characteristics and species assemblages have the potential to support more diverse wildlife communities.

Discussion and Conclusions

Southern forests are productive, dynamic, and diverse, supporting a vast array of wildlife communities. They support resident wildlife communities, and play a vital role in the conservation of migratory bird populations. Increased demand on southern forest resources has created complex situations for natural resource managers. Managers balance timber resource needs with habitat requirements for wildlife communities. These challenges must be faced at both the stand and the landscape level. Demand for forest products is increasing, placing greater demands on southern forests for wood production.

Ownership patterns complicate southern forest management. The majority of land in the South is held by a plethora of private owners with a wide variety of management objectives. To be effective, conservation efforts for many wildlife species must cover entire landscapes. Large-scale projects such as Partners in Flight and conservation efforts with Louisiana black bears require cooperation among forest industry, Federal and State government agencies, and nonindustrial private landowners.

At the stand level, practices for improving specific aspects of wildlife habitat in intensively managed forests can be highly beneficial. Retaining mature trees and snags in intensively managed stands provides structural complexity that many wildlife species require. Maintaining SMZs provides travel corridors for wildlife, increases structural and compositional complexity, and prevents detrimental impacts to streams.

Early successional habitat is critical for many wildlife species. Forest management practices geared toward establishing new stands provide abundant early successional habitat, but the wildlife benefits of these stands decreases after canopy closure.

Southern forests are created and maintained by natural and human-induced disturbances. These disturbances shape the structure and composition of forests and the wildlife communities that depend on them. Land use patterns are constantly changing. The changes are beneficial to some wildlife communities and detrimental to others.

Needs for Additional Research

Although copious amounts of very creditable work have been directed at the effects of plantation management on wildlife communities, particularly birds, most of it has been directed at younger stands. The benefits of providing early successional habitat are undeniable, but very little information exists comparing young plantations with different land use histories. Another area that should be given additional attention is midrotation pine plantations. Stands that have reached canopy closure but have not reached a condition to warrant thinning should be more thoroughly examined for wildlife use.

Literature Cited

Abrahamson, W.G.; Hartnett, D.C. 1990. Pine flatwoods and dry prairies. In: Myers, R.L.; Ewel, J.J., eds. Ecosystems of Florida. Orlando, FL: University of Central Florida Press: 103–149.

Ambuel, B.; Temple, S.A. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology. 64: 1057–1068.

Anders, A.D.; Faaborg, J.; Thompson, F.R., III. 1998. Postfledging dispersal, habitat use, and home-range size of juvenile wood thrushes. Auk. 115: 349–358.

Annand, E.M.; Thompson, F.R., III. 1997. Forest bird response to regeneration practices in central hardwood forests. Journal of Wildlife Management. 61: 159–171.

Aresco, M.J.; Guyer, C. 1999. Burrow abandonment by gopher tortoises in slash pine plantations of the Conecuh National Forest. Journal of Wildlife Management. 63: 26–35.

Ash, A.N. 1997. Disappearance and return of salamanders to clearcut plots in the southern Blue Ridge. Conservation Biology. 11: 983–989.

Ash, A.N.; Pollock, K.H. 1999. Clearcuts, salamanders, and field studies. Conservation Biology. 13: 206–208.

Askins, R.A. 2001. Sustaining biological diversity in early successional communities: the challenge of managing unpopular habitats. Wildlife Society Bulletin. 29: 407–412.

Ayers, H.B.; Ashe, W.W. 1905. The Southern Appalachian forests. U.S. Geol. Surv. Prof. Pap. 37. Washington, DC: U.S. Government Printing Office. 232 p.

Baker, J.B.; Broadfoot, W.M. 1979. Site evaluation for commercially important southern hardwoods. Gen. Tech. Rep. SO–26. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 51 p.

Baker, J.C. 1997. Assessment of plant diversity in a spatial chronosequence on Delta National Forest in Mississippi. Mississippi State, MS: Mississippi State University, College of Forest Resources. [Number of pages unknown].

Barber, D.R.; Martin, T.E.; Melchiors, M.A. [and others]. 2001. Nesting success of birds in different silvicultural treatments in Southeastern U.S. pine forests. Conservation Biology. 15: 196–207.

Barden, L.S. 2000. A common species at the edge of its range: conservation of bear oak *(Quercus ilicifolia)* and its low elevation rocky summit community in North Carolina (U.S.A.). Natural Areas Journal. 20: 85–89.

Bartram, W. 1998. The travels of William Bartram: Francis Harper's naturalist edition. Athens, GA: University of Georgia Press. 749 p.

Beilman and Brenner. 1951. The recent intrusion of forests in the Ozarks. Annals of the Missouri Botanical Gardens. 38: 261–282.

Belue, T.F. 1996. The long hunt: death of the buffalo east of the Mississippi. Mechanicsburg, PA: Stackpole Books. 237 p.

Blake, J.G.; Karr, J.R. 1987. Breeding birds in isolated woodlots: area and habitat relationships. Ecology. 68: 1724–1734.

Bonnicksen, T.M. 2000. America's ancient forest: from the Ice Age to the age of discovery. [New York]: John Wiley. 594 p.

Bourque, J.; Villard, M.A. 2001. Effects of selection cutting and landscape-scale harvesting on the reproductive success of two neotropical migrant bird species. Conservation Biology. 15: 184-195.

Brawn, J.D.; Robinson, S.K.; Thompson, F.R., III. 2001. The role of disturbance in the ecology and conservation of birds. Annual Review of Ecological Systems. 32: 251–276.

Brittingham, M.C.; Temple, S.A. 1983. Have cowbirds caused forest songbirds to decline? Bioscience. 33: 31–35.

Brunjes, J.H. 1998. The effects of prescribed winter burning on avian communities in mature pine habitats. Athens, GA: University of Georgia. 79 p. M.S. thesis.

Buckner, E.R.; Turrill, N.L. 1999. Fire management. In: Peine, J.D., ed. Ecosystem management for sustainability: principles and practices. Boca Raton, FL: St. Lucie Press: 329–347.

Burke, D.M.; Nol, E. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. Auk. 115: 96–104.

Caine, L.A.; Marion, W.R. 1991. Artificial addition of snags and nest boxes to slash pine plantations. Journal of Field Ornithology. 62: 97–106.

Capel, S.; Carmichael, B.; Gudlin, M.; Long, D. 1994. Wildlife needs assessment: southeast region. Washington, DC: The Wildlife Management Institute. 16 p.

Chazal, A.E.; Niewiarowski, P.H. 1998. Responses of mole salamanders to clearcutting: using field experiments in forest management. Ecological Applications. 8: 1133–1143.

Clark, J.; Pelton, M. 1999. Management of a large carnivore: black bear. In: Peine, J.D., ed. Ecosystem management for sustainability: principles and practices. Boca Raton, FL: St. Lucie Press: 209–224.

Cook, J.A. 2000. Disturbance history of two natural areas in Wisconsin: implications for management. Natural Areas Journal. 20: 24–35.

Croker, T.C., Jr. 1987. Longleaf pine, a history of man and a forest. For. Rep. R8–FR 7. [New Orleans]: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 37 p.

Delcourt, H.R.; Delcourt, P.A. 1997. Pre-Columbian Native American use of fire on Southern Appalachian landscapes. Conservation Biology. 11: 1010–1014.

Delcourt, P.A.; Delcourt, H.R. 1998. Paleoecological insights on conservation of biodiversity: a focus on species, ecosystems, and landscapes. Ecological Applications. 8: 921–934.

deMaynadier, P.G.; Hunter, M.L., Jr. 2000. Road effects on amphibian movements in a forested landscape. Natural Areas Journal. 20: 56–65.

Diamond, S.J.; Giles, R H., Jr.; Kirkpatrick, R.L.; Griffin, G.J. 2000. Hard mast production before and after the chestnut blight. Southern Journal of Applied Forestry. 24(4): 196–201.

Dickson, J.G., ed. 2001. Wildlife of southern forests: habitat and management. Blaire, WA: Hancock House Publishers. 480 p.

Dickson, J.G.; Conner, R.N.; Williamson, J.H. 1983. Snag retention increases bird use of a clear-cut. Journal of Wildlife Management. 47: 799–804.

Dickson, J.G.; Thompson, F.R., III; Conner, R.N.; Franzreb, K.E. 1993. Effects of silviculture on neotropical migratory birds in central and southeastern oak-pine forests. In: Finch, D.M.; Stangel, P.W., eds. Status and management of neotropical migratory birds. Gen. Tech. Rep. RM–229. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 374–385.

Dickson, J.G.; Thompson, F.R., III; Conner, R.N.; Franzreb, K.E. 1995. Silviculture in central and southeastern oak-pine forests. In: Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. Oxford, NY: Oxford University Press: 245–265.

Dijak, W.D.; Thompson, F.R., III. 2000. Landscape and edge effects on the distribution of mammalian predators in Missouri. Journal Wildlife Management. 64: 209–216.

Donovan, T.M.; Jones, P.W.; Annand, E.M.; Thompson, F.R., III. 1997. Variation in local-scale edge effects: mechanisms and landscape context. Ecology. 78: 2064–2075.

Donovan, T.M.; Thompson, F.R., III. 2001. Modeling the ecological trap hypothesis: a habitat and demographic analysis for migrant songbirds. Ecological Applications. 11: 871–882.

Dugay, J.P.; Wood, P.B.; Nichols, J.V. 2001. Songbird abundance and avian nest survival rates in forests fragmented by different silvicultural treatments. Conservation Biology. 15: 1405–1415.

Dunning, J.B., Jr.; Borgella, R., Jr.; Clements, K.; Meffe, G.K. 1995. Patch isolation, corridor effects, and colonization by a resident sparrow in a managed pine woodland. Conservation Biology. 9: 542–550.

Farnesworth, G.L.; Simons, T.R. 1999. Factors affecting nesting success of wood thrushes in Great Smoky Mountains National Park. Auk 116: 1075–1082.

Fitzgerald, J.A.; Bart, J.; Brown, H.D.; Lee, K. [In press]. Birds in a developing area: the need for habitat protection at the landscape scale. Journal of Field Ornithology.

Flaspohler, D.J.; Temple, S.A.; Rosenfeld, R.N. 2001a. Effects of forest edges on ovenbird demography in a managed forest landscape. Conservation Biology. 15: 173–183.

Flaspohler, D.J.; Temple, S.A.; Rosenfeld, R.N. 2001b. Species-specific edge effects on nest success and breeding bird density in a forested landscape. Ecological Applications. 11: 32–46.

Freemark, K.; Collins, B. 1992. Landscape ecology of birds breeding in temperate forest fragments. In: Hagan, J.M., III; Johnston, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, DC: Smithsonian Institution Press: 443–454.

Frost, C.C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. In: Hermann, S.M., ed. The longleaf pine ecosystem: ecology, restoration and management. Proceedings of the 18th Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 17–43.

Frost, C.C. 1995. Presettlement fire regimes in southeastern marshes, peatlands, and swamps. In: Cerulean, S.I.; Engstrom, R.T., eds. Fire in wetlands: a management perspective. Proceedings of the 19th Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 39–60.

Frost, C.C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. In: Pruden, T.L.; Brennan, L.A., eds. Fire in ecosystem management: shifting the paradigm from suppression to prescription. Proceedings of the 20th Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 70–81.

Gale, G.A.; Hanners, L.A.; Patton, S.R. 1997. Reproductive success of worm-eating warblers in a forested landscape. Conservation Biology. 11: 246–250.

Gates, J.E.; Gysel, L.W. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology. 59: 871–883.

Gibbs, J.P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management. 62: 584–589.

Graves, G.R. 1997. Geographic clines of age ratios of black-throated blue warblers (*Dendroica caerulescens*). Ecology. 78: 2524–2531.

Gross, K.; Lockwood, J.R., III; Frost, C.C.; Morris, W.F. 1998. Modeling controlled burning and trampling reduction for conservation of *Hudsonia montana*. Conservation Biology. 12: 1291–1301.

Hagan, J.M.; McKinley, P.S.; Mechan, A.L.; Grove, S.L. 1997. Diversity and abundance of landbirds in a northeastern industrial forest. Journal of Wildlife Management. 61: 718–735.

Hagan, J.M.; Vander Haegen, W.M.; McKinley, P.S. 1996. The early development of forest fragmentation effects on birds. Conservation Biology. 10: 188–202.

Hamel, P.B.; Buckner, E.R. 1998. How far could a squirrel travel in the treetops? A prehistory of the southern forest. Transactions, North American Wildlife and Natural Resources Conference. 63: 309–315.

Harris, L.D. 1984. The fragmented forest. Chicago: University of Chicago Press. 211 p.

Harris, R.J.; Reed, J.M. 2001. Territorial movements of black-throated blue warblers in a landscape fragmented by forestry. Auk. 118: 544–549.

Hartley, M.J.; Hunter, M.L., Jr. 1998. A meta-analysis of forest cover, edge effects, and artificial nest predation rates. Conservation Biology. 12: 465–469.

Haskell, D.G. 2000. Effects of forest roads on macroinvertebrate soil fauna of the Southern Appalachian Mountains. Conservation Biology. 14: 57–63.

Hedrick, L.D.; Hooper, R.G.; Krusac, D.L.; Dabney, J.M. 1998. Silvicultural systems and red-cockaded woodpecker management: another perspective. Wildlife Society Bulletin. 26: 138–147.

Hefner, J.M.; Wilen, B.O.; Dahl, T.E.; Frayer, W.E. 1995. Southeast wetlands status and trends, mid-1970s to mid-1980s. Atlanta: U.S. Department of the Interior, Fish and Wildlife Service. 32 p.

Herbeck, L.A.; Larsen, D.R. 1999. Plethodontid salamander responses to silvicultural practices in Missouri Ozark forests. Conservation Biology. 13: 623–632.

Hodges, J. 1997. Development and ecology of bottomland hardwood sites. Forest Ecology and Management. 90: 117–125.

Holmes, R.T.; Sherry, T.W. 2001. Thirty-year bird population trends in an unfragmented temperate deciduous forest: importance of habitat change. Auk. 118: 589–609.

Holt, J.P. 2000. Changes in bird populations on the Highlands Plateau, North Carolina (U.S.A.), 1946–1995, with emphasis on neotropical migrants. Natural Areas Journal. 20: 119–125.

Howell, M.A. 1998. Avian nesting success in mature pine stands maintained by prescribed fire in Georgia. Athens, GA: University of Georgia. [Number of pages unknown]. M.S. thesis.

Hunter, W.C.; Buehler, D.A.; Canterbury, R.A. [and others]. 2001. Conservation of disturbance-dependent birds in Eastern North America. Wildlife Society Bulletin. 29: 440–455.

Hunter, W.C.; Dickson, J.G.; Pashley, D.N.; Hamel, P.B. 2001. Bird communities of southern forests. In: Dickson, J.G., ed. Wildlife of southern forests: habitat and management. Blaire, WA: Hancock House Publishers: 322–349.

Hunter, W.C.; Mueller, A.J.; Hardy, C.L. 1994. Managing for red-cockaded woodpeckers and Nearctic-neotropical migrants—is there a conflict? Proceedings of the annual conference of the Southeast Association of Fish and Wildlife Agencies. 48: 383–394.

James, F.C.; McCulloch, C.E.; Wiedenfeld, D.A. 1996. New approaches to the analysis of population trends in land birds. Ecology. 77: 13–27.

Karriker, K.S. 1993. Effects of intensive silviculture on breeding and wintering birds in North Carolina pocosins. Raleigh, NC: North Carolina State University, Department of Forestry. 217 p. M.S. thesis.

Keyser, A.J.; Hill, G.E.; Soehren, E.C. 1998. Effect of forest fragment size, nest density, and proximity to edge on the risk of predation to ground-nesting passerine birds. Conservation Biology. 12: 986–994.

Kilgo, J.C.; Miller, K.V.; Smith, W.P. 1999. Effects of group-selection timber harvest in bottomland hardwoods on fall migrant birds. Journal of Field Ornithology. 70: 404–413.

Kilgo, J.C.; Sargent, R.A.; Chapman, B.R.; Miller, K.V. 1996. Nest-site selection by hooded warblers in bottomland hardwoods of South Carolina. Wilson Bulletin. 108: 53–60.

Kilgo, J.C.; Sargent, R.A.; Chapman, B.R.; Miller, K.V. 1998. Effect of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. Journal of Wildlife Management. 62: 72–83.

Kilgo, J.C.; Sargent, R.A.; Miller, R.N.; Chapman, B.R. 1997. Landscape influences on breeding bird communities in hardwood fragments in South Carolina. Wildlife Society Bulletin. 25: 878–885.

King, D.I.; Griffin, C.R.; DeGraaf, R.M. 1996. Effects of clearcutting on habitat use and reproductive success of the ovenbird in forested landscapes. Conservation Biology. 10: 1380–1386.

Krementz, D.G.; Jackson, J.J. 1999. Woodcock in the Southeast: natural history and management for landowners. Coop. Ext. Ser. Bull. 1183. [Athens, GA]: The University of Georgia, College of Agricultural and Environmental Sciences. 16 p.

Kricher, J.C.; Davis, W.E., Jr. 1992. Patterns of avian species richness in disturbed and undisturbed habitats in Belize. In: Hagan, J.M., III; Johnston, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, DC: Smithsonian Institution Press: 240–246.

Land, D.; Marion, W.R.; O'Meara, T.E. 1989. Snag availability and cavity nesting birds in slash pine plantations. Journal of Wildlife Management. 53: 1165–1171.

Landers, J.L.; Van Lear, D.H.; Boyer, W.D. 1995. The longleaf pine forests of the Southeast: requiem or renaissance? Journal of Forestry. 93: 39–44.

Larem, J. 1996. Disappearing Southern Appalachian balds. Southern Wildlife. 1(3): 24–31.

Lee, D.S. 1986. Pocosin breeding bird fauna. American Birds. 40: 1263–1273.

Lee, D.S. 1987. Breeding birds of Carolina bays: succession related density and diversification on ecological islands. The Chat. 51: 85–102.

Lee, D.S.; Norden, A.W. 1996. The distribution, ecology, and conservation needs of bog turtles, with special emphasis on Maryland. The Maryland Naturalist. 40: 7–46.

Lichstein, J.W.; Simons, T.R.; Franzreb, K.E. 2002. Landscape effects on breeding songbird abundance in managed forests. Ecological Applications. 12: 836–857.

Litvaitis, J.A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology. 7: 866–873.

Litvaitis, J.A.; Villafuerte, R. 1996. Factors affecting the persistence of New England cottontail metapopulations: the role of habitat management. Wildlife Society Bulletin. 24: 686–693.

Litvaitis, J.A.; Wagner, D.L.; Confer, J.L. [and others]. 1999. Early-successional forests and shrub-dominated habitats: land-use artifact or critical community in the Northeastern United States? Northeast Wildlife. 54: 101–118.

Machtans, C.S.; Villard, M.A.; Hannon, S.J. 1996. Use of riparian strips as movement corridors by forest birds. Conservation Biology. 10: 1366–1379.

Manolis, J.C.; Anderson, D.E.; Cuthbert, F.J. 2000. Patterns in clearcut edge and fragmentation effect studies in northern hardwood-conifer landscapes: respective power analysis and Minnesota results. Wildlife Society Bulletin. 28: 1088–1101.

Marzluff, J.M. 2001. Restoration of fragmented landscapes for the conservation of birds: a general framework and specific recommendations for urbanizing landscapes. Restoration Ecology. 9: 280–292.

McCoy, E.D.; Mushinsky, H.R. 1999. Habitat fragmentation and the abundances of vertebrates in the Florida scrub. Ecology. 80: 2526–2538.

McLachlan, J.S.; Foster, D.R.; Menalled, F. 2000. Anthropogenic ties to late-successional structure and composition in four New England hemlock stands. Ecology. 81: 717–733.

Means, D.B.; Palis, J.G.; Baggett, M. 1996. Effects of slash pine silviculture on a Florida population of flatwoods salamander. Conservation Biology. 10: 426–437.

Melchiors, M.A.; Chapman, B.R.; Gerwin, J.A. [and others]. [In press]. Managing habitat for priority landbirds in loblolly, shortleaf, and slash pine forests of the Southeast. . [Athens, GA]: University of Georgia Press.

Menzel, M.A.; Carter, T.C.; Ford, W.M.; Chapman, B.R. 2001. Tree-roost characteristics of subadult and female adult evening bats *(Nycticeius humeralis)* in the upper Coastal Plain of South Carolina. American Midland Naturalist. 145: 112–119.

Milling, T.C.; Rowe, M.P.; Cockerel, B.L. [and others]. 1998. Population densities of northern saw-whet owls in degraded boreal forests of the Southern Appalachians. In: Duncan, J.R.; Johnston, D.H.; Nicholls, T.H., eds. Biology and conservation of owls of the Northern Hemisphere. Gen. Tech. Rep. NC–190. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 272-285.

Mitchell, M.S.; Lancia, R.A.; Gerwin, J.A. 2001. Using landscape-level data to predict the distribution of birds on a managed forest: effects of scale. Ecological Applications. 11: 1692–1708.

Mitchell, M.S.; Karriker, K.S.; Jones, E.J.; Lancia, R.A. 1995. Small mammal communities associated with pine plantation management of pocosins. Journal of Wildlife Management. 59: 875–881.

Moler, P.E.; Franz, R. 1987. Wildlife values of small, isolated wetlands in the southeastern Coastal Plain. In: Odum, R.R.; Riddleberger, K.A.; Ozier, J.C., eds. Proceedings of the third southeastern nongame and endangered wildlife symposium. Atlanta: Georgia Department of Natural Resources: 234–241.

Moorman, C.E.; Russell, K.R.; Sabin, G.R.; Guynn, D.C., Jr. 1999. Snag dynamics and cavity occurrence in the South Carolina Piedmont. Forest Ecology and Management. 118: 37–48.

Myers, R.L. 1990. Scrub and high pine. In: Myers, R.L.; Ewel, J.J., eds. Ecosystems of Florida. Orlando, FL: University of Central Florida Press: 150–193.

National Association of Conservation Districts. 1994. Riparian ecosystems in the humid U.S.: functions, values, and management. Washington, DC: National Association of Conservation Districts. [Number of pages unknown].

Nelson, J. 1992. The vanishing blackjacks. South Carolina Wildlife. 39: 34–39.

Nicholas, N.S.; Eagar, C.; Peine, J.D. 1999. Threatened ecosystem: high-elevation spruce-fir forest. In: Peine, J., ed. Ecosystem management for sustainability: principles and practices. Boca Raton, FL: St. Lucie Press: 431–454.

Noss, R.F.; La Roe, E.T., III; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biol. Rep. 28. Washington, DC: U.S. Department of the Interior, National Biological Survey. [Number of pages unknown].

Oliver, C.D. 1981. Forest development in North America following major disturbance. Forest Ecology and Management. 3: 153–168.

Oliver, C.D.; Larson, B.C. 1990. Forest stand dynamics. New York: McGraw-Hill. 467 p.

Opler, P.A.; Krizek, G.O. 1984. Butterflies east of the plains. Baltimore: John Hopkins University Press. [Number of pages unknown].

Ortega, Y.K.; Capen, D.E. 1999. Effects of forest roads on habitat quality for ovenbirds in a forested landscape. Auk. 116: 937–946.

Pagen, R.W.; Thompson, F.R., III; Burhans, D.E. 2000. Breeding and post-breeding habitat use by forest migrant songbirds in the Missouri Ozarks. Condor. 102: 738–747.

Pashley, D.N.; Barlow, W.C. 1993. Effects of land use practices on neotropical migratory birds in bottomland hardwood forests. In: Finch, D.M.; Stangel, P.W., eds. Status and management of neotropical migratory birds. Gen. Tech. Rep. RM–229. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 315–320.

Perry, R.W.; Thill, R.E.; Peitz, D.G.; Tappe, P.A. 2000. Effects of different silvicultural systems on initial soft mast production. Wildlife Society Bulletin. 27: 915–923.

Petranka, J.W. 1999. Recovery of salamanders after clearcutting in the Southern Appalachians: a critique of Ash's estimates. Conservation Biology. 13: 203–205.

Petranka, J.W.; Eldridge, M.E.; Haley, K.E. 1993. Effects of timber harvesting on Southern Appalachian salamanders. Conservation Biology. 7: 363–370.

Pietz, D.G.; Tappe, P.A.; Shelton, M.G.; Sams, M.G. 1999. Deer browse response to pine-hardwood thinning regimes in southeastern Arkansas. Southern Journal of Applied Forestry. 23(1): 16–20.

Pornezuli, P.; Berdnarz, J.C.; Goodrich, L.J. [and others]. 1993. Reproductive performance of territorial ovenbirds occupying forest fragments and contiguous forest in Pennsylvania. Conservation Biology. 7: 618–622.

Porneluzi, P.; Faaborg, J. 1999. Season-long fecundity, survival, and viability of ovenbirds in fragmented and unfragmented landscapes. Conservation Biology. 13: 1151–1161.

Powell, L.A.; Lang, J.D.; Conroy, M.J.; Krementz, D.G. 2000. Effects of forest management on density, survival, and population growth of wood thrushes. Journal of Wildlife Management. 64: 11–23.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist. 132: 652–661.

Rabenold, K.N.; Fauth, P.T.; Goodner, B.W.; [and others]. 1998. Response of avian communities to disturbance by an exotic insect in spruce-fir forests of the Southern Appalachians. Conservation Biology. 12: 177–189.

Raftovitch, R.V., Jr. 1998. Effects of management for red-cockaded woodpeckers on avian communities in mature pine stands in the Georgia Piedmont. Athens, GA: The University of Georgia. [Number of pages unknown]. M.S. thesis.

Reynolds, R.R. 1980. The Crossett story, the beginning of forestry in southern Arkansas and northern Louisiana. GTR SO–32. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 40 p.

Rich, A.C.; Dobkin, D.S.; Niles, L.J. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology. 8: 1109–1121.

Richardson, C.J.; Gibbons, J.W. 1993. Pocosins, Carolina bays, and mountain bogs. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, lowland terrestrial communities. New York: John Wiley: 257–310.

Robbins, C.S. 1980. Effect of forest fragmentation on breeding bird populations in the Piedmont of the mid-Atlantic region. American Naturalist. 33: 31–36.

Robbins, C.S.; Dawson, D.K.; Dowell, B.A. 1989a. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildlife Monographs. 103: 1-34.

Robbins, C.S.; Sauer, J.R.; Greenberg, R.; Droege, S. 1989b. Population declines in North American birds that migrate to the neotropics. Proceedings of the National Academy of Science. 86: 7658–7662.

Robinson, S.K. 1992. Population dynamics of breeding neotropical migrants in the fragmented Illinois landscape. In: Hagan, J.M., III; Johnston, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, DC: Smithsonian Institution Press: 408–418.

Robinson, S.K. 1996. Threats to breeding neotropical migratory birds in the Midwest. In: Thompson, F.R., III, ed. Management of Midwestern landscapes for the conservation of neotropical migratory birds. Gen. Tech. Rep. NC–187. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experimental Station: 1–21.

Robinson, S.K.; Thompson, F.R., III; Donovan, T.M. [and others]. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science. 267: 1987–1990.

Rosenberg, K.V.; Lowe, J.D.; Dhondt, A.A. 1999. Effects of forest fragmentation on breeding tanagers: a continental perspective. Conservation Biology. 13: 568–583.

Rudis, V.A.; Tansey, J.B. 1995. Regional assessment of remote forests and black bear habitat from forest resource surveys. Journal of Wildlife Management. 59: 170–180.

Saenz, D.; Conner, R.N.; Rudolph, D.C.; Engstrom, R.T. 2001. Is a "hands-off" approach appropriate for red-cockaded woodpecker conservation in 21st century landscapes? Wildlife Society Bulletin. 29: 956–966.

Semlitsch, R.A. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology. 12: 1113–1119.

Sharitz, R.R.; Mitsch, W.J. 1993. Southern floodplain forests. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, lowland terrestrial communities. New York: John Wiley: 311–372.

Sherry, T.W. 2000. Shade coffee: a good brew even in small doses. Auk. 117: 563–568.

Simons, T.R.; Farnsworth, G.L.; Shriner, S.A. 2000. Evaluating Great Smoky Mountains National Park as a population source for the wood thrush. Conservation Biology. 14: 1133–1144.

Simpson, M.B., Jr. 1992. Birds of the Blue Ridge Mountains. Chapel Hill, NC: University of North Carolina Press. 354 p.

Southern Appalachian Man and the Biosphere (SAMAB). 1996. The Southern Appalachian assessment terrestrial technical report. Rep. 5 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 288 p.

Stout, I.J.; Marion, W.R. 1993. Pine flatwoods and xeric pine forests of the southern (lower) Coastal Plain. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, lowland terrestrial communities. New York: John Wiley: 373–446.

Suthers, H.H.; Bickal, J.M.; Rodewald, P.G. 2000. Use of successional habitat and fruit resources by songbirds during autumn migration in central New Jersey. Wilson Bulletin. 112: 249–260.

Temple, S.A.; Cary, J.R. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biology. 2: 340–347.

Terborgh, J. 1989. Where have all the birds gone? Princeton, NJ: Princeton University Press. 207 p.

Thompson, F.R., III; Dijak, W.D.; Kulowiec, T.G.; Hamilton, D.A. 1992. Effects of even-aged forest management on breeding bird densities. Journal of Wildlife Management. 56: 23–29.

Trani, M.K.; Brooks, R.T.; Schmidt, T.L. [and others]. 2001. Patterns and trends of early successional forests in the Eastern United States. Wildlife Society Bulletin. 29: 413–424.

Trzcinski, M.K.; Fahrig, L.; Merriam, G. 1999. Independent effects of forest cover and fragmentation on the distribution of forest breeding birds. Ecological Applications. 9: 586–593.

U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita Highlands assessment: terrestrial vegetation and wildlife. Rep. 5 of 5. Gen. Tech. Rep. SRS–35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 201 p.

U.S. Fish and Wildlife Service. 2000. Technical/agency draft revised recovery plan for the red-cockaded woodpecker (*Picoides borealis*). Atlanta: U.S. Fish and Wildlife Service. 229 p.

Vega Rivera, J.H.; McShea, W.J.; Rappole, J.H.; Haas, C.A. 1999. Postbreeding movements and habitat use of adult wood thrushes in northern Virginia. Auk. 116: 458–466.

Vega Rivera, J.H.; Rappole, J.H.; McShea, W.J.; Haas, C.A. 1998. Wood thrush postfledging movements and habitat use in northern Virginia. Condor. 100: 69–78.

Villard, M.A. 1998. On forest-interior species, edge avoidance, area sensitivity, and dogma in avian conservation. Auk. 115: 801–805.

Walker, L.C. 1991. The southern forest: a chronicle. Austin, TX: University of Texas Press. 322 p.

Ware, S.; Frost, C.; Doerr, P.D. 1993. Southern mixed hardwood forest: the former longleaf pine forest. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, lowland terrestrial communities. New York: John Wiley: 447–494.

White, P.S. 1984. The Southern Appalachian spruce-fir ecosystem: an introduction. In: White, P.S., ed. The Southern Appalachian spruce-fir ecosystem: its biology and threats. Res. Resour. Manage. Rep. SER–71. Atlanta: U.S. Department of the Interior, National Park Service. [Number of pages unknown].

White, P.S.; Buckner, E.; Pittillo, J.D.; Cogbill, C.V. 1993. High-elevation forests: spruce-fir forests, northern hardwoods forest, and associated communities. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States, upland terrestrial communities. New York: John Wiley: 305–338.

White, P.S.; White, R.D. 1996. Old-growth oak and oak-hickory forests. In: Byrd, M.D., ed. Eastern old-growth forests: prospects for rediscovery and recovery. Washington, DC: Island Press: 178–198.

Wigley, T.B.; Baughman, W.M.; Dorcas, M.E.; [and others]. 2000. Contributions of intensively managed forests to the sustainability of wildlife communities in the South. In: Sustaining southern forests: the science of forest assessment. Southern Forest Resource Assessment. http://www.srs.fs.fed.us/sustain/conf/abs/wigley.htm. [Date accessed: August 20, 2002].

Wigley, T.B.; Melchiors, M.A. 1994. Wildlife habitat and communities in streamside management zones: a literature review for the Eastern United States. In: Riparian ecosystems in the humid U.S.: functions, values, and management. Washington, DC: National Association of Conservation Districts: 100–121.

Wigley, T.B.; Miller, K.V.; deCalesta, D.S.; Thomas, M.W. 2002. Herbicides as an alternative to prescribed burning for achieving wildlife management objectives. In: Ford, M.W.; Russell, K.R.; Moorman, C.E., eds. The role of fire for nongame wildlife management and community restoration: traditional uses and new directions: Proceedings. Gen. Tech. Rep. NE–288. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 124–138.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology. 66: 1211–1214.

Wilcove, D.S. 1988. Changes in the avifauna of the Great Smoky Mountains: 1947–1983. Wilson Bulletin. 100: 256–271.

Williams, C.E. 1998. History and status of Table Mountain pine-pitch pine forests of the Southern Appalachian Mountains (U.S.A.). Natural Areas Journal. 17: 81–90.

Wilson, C.W.; Masters, R.E.; Bukenhofer, G.A. 1995. Breeding bird response to pine-grassland community restoration for red-cockaded woodpeckers. Journal of Wildlife Management. 59: 56–66.

Wilson, M.D.; Watts, B.D. 1999a. Breeding bird communities of a managed forest landscape in coastal North Carolina. Willamsburg, VA: College of William and Mary. 86 p. [Report to Weyerhauser Company from Center of Conservation Biology].

Wilson, M.D.; Watts, B.D. 1999b. Response of brown-headed nuthatches to thinning of pine plantations. Wilson Bulletin. 111: 56–60.

Woolfendon, G.E. 1996. Florida scrub-jay. In: Rodgers, J.A., Jr.; Kale, H.W., II; Smith, H.T., eds. Rare and endangered biota of Florida. Gainesville, FL: University Press of Florida: 267–280. Vol. 5.

What conditions will be needed to maintain animal species associations in the South?

Chapter 5: Maintaining Species in the South

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Key Findings

- Geographic patterns of diversity in the South indicate that species richness is highest in Texas, Florida, North Carolina, and Georgia. Texas leads in the richness of mammals, birds, and reptiles; North Carolina leads in amphibian diversity. Texas dominates vertebrate richness by virtue of its large size and the variety of its ecosystems.
- Loss of habitat is the primary cause of endangerment of terrestrial vertebrates. Forests, grasslands, shrublands, and wetlands have been converted to urban, industrial, and agricultural uses. Other factors include environmental contaminants, commercial exploitation, coastal development, fire suppression, river and stream modification, and wetland degradation.
- Species that are federally listed as threatened or endangered consist of 22 birds, 33 mammals, 7 amphibians, and 17 reptiles. Florida leads with the number of threatened (16) and endangered (26) vertebrates; Texas is second in endangered species (23); while Mississippi is second in the number of threatened species (11).
- Birds of high concern include the red-cockaded woodpecker, bald eagle, piping plover, whooping crane, wood stork, black-capped vireo, Florida scrub jay, and the roseate and least terns.
- Habitat destruction and the paucity of large tracts of undisturbed land threaten far-ranging mammals such as the Florida panther, red wolf, and the Louisiana black bear. Other mammals of concern include the Carolina and Virginia northern flying squirrels, the river otter, and several rodents.
- Twenty species of bats inhabit the South. Four are listed as endangered: the gray bat, Indiana bat, and Ozark and Virginia big-eared bats. Human disturbance to hibernation and maternity colonies is a major factor in their decline.
- The South is the center of amphibian biodiversity in the Nation. However, there are growing concerns about amphibian declines. Potential causes include habitat destruction, exotic species, water pollution, ozone depletion leading to excessive ultraviolet radiation, acid deposition, synthetic chemicals, and prolonged drought conditions.
- Seven species of amphibians are listed as threatened or endangered by the U.S. Fish and Wildlife Service: the Houston toad, Flatwoods salamander, San Marcos salamander, Barton Springs salamander, Red Hills salamander, Shenandoah Mountain salamander, and Texas blind salamander. These species are imperiled due to physiological constraints that limit them to moist habitats, relatively small ranges, and highly specific sites.
- Reptile species of concern include the Louisiana pine snake, eastern indigo snake, crocodile, glass lizard, bluetail mole skink, gopher tortoise, and bog turtle. General problems faced by reptiles include habitat destruction, pet trade, negative public attitudes, degradation of aquatic habitats, and fire suppression or the lack of sufficient prescribed burning.
- Many reptiles and amphibians are long-lived and late maturing, and have restricted geographic ranges. Managing for these species will require different strategies than those in place for birds and mammals. The paucity of monitoring data further inhibits their management.

Introduction

The biodiversity of the South is impressive. Factors contributing to that diversity include regional gradients in climate, geologic and edaphic site conditions, topographic variation, natural disturbance processes, and the activities of Native Americans and European settlers (Boyce and Martin 1993, Delcourt and others 1993, Healy 1985). These factors have contributed to the diversity of several species groups: salamanders, snakes, and turtles (White and others 1998). The evolution of plants and animals, combined with the isolation that characterizes some habitats, produced remarkable levels of endemism—species that are restricted to special habitats.

The terrestrial vertebrate fauna of the South, including the entire States of Texas and Oklahoma, consists of 1,208 species. This total includes 170 amphibians, 197 reptiles, 595 birds, and 246 mammals (NatureServe 2000). Species richness is highest in Texas, Florida, North Carolina, and Georgia (fig. 5.1). North Carolina leads in amphibian diversity, while Texas leads in the richness of mammals, birds, and reptiles.

The variation in species richness among States is influenced by

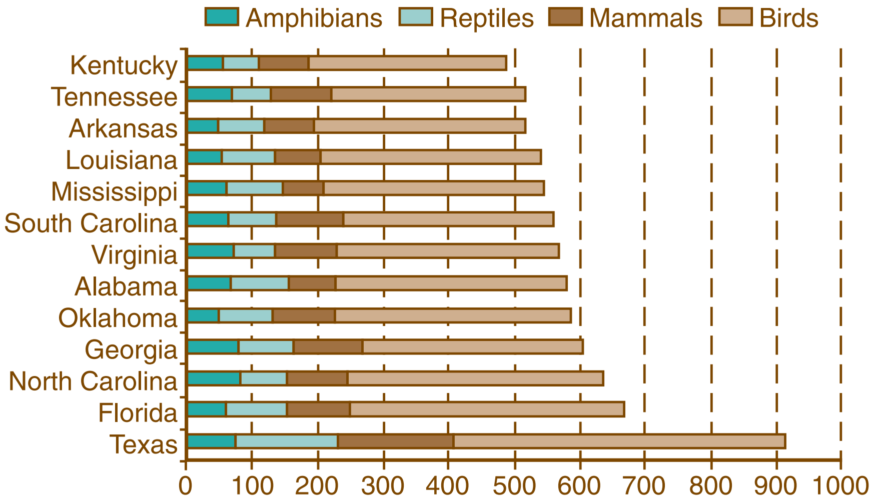

Figure 5.1—Geographic patterns of diversity by State within the South (NatureServe 2000).

differences in size, geographic location, and environmental complexity (Stein and others 2000). Texas leads the region with 911 vertebrate species; diversity there is influenced by the State's large size and its diversity of habitats (NatureServe 2000). Florida, North Carolina, and Georgia each support over 600 vertebrate species. The smallest number of species (487) occurs in Kentucky. Texas and Florida support species typical of Latin America and the Caribbean that reach their northern limits there (Stein and others 2000). For example, the northern limit for the American crocodile is in the Florida Keys and south Florida.

This diverse array of vertebrate species is found in a variety of habitats. A habitat is comprised of the physical and biological resources that allow a species to survive and reproduce. The habitat requirements for some species may be quite narrow, while those for another may be rather broad.

A species may require a certain habitat structure such as vegetation height, percent canopy cover, floristics, seral stage, patch size, or diversity and interspersion of plant communities. Some species are constrained by abiotic factors such as the precise cave temperatures required by many bat species. These features of habitat influence the distribution and abundance of species (Dickson 2001).

The habitat conditions for southern species have been modified by several factors (Buckner 1989). Habitat loss and degradation are serious threats to the region's fauna (Noss and others 1995, Williams 1989). The rapid growth of the human population has resulted in land use conversion, urban sprawl, and habitat fragmentation (White and others 1998). Landscape modification has been accompanied by habitat isolation, water and air pollution, and altered disturbance regimes (Lorimer 2001, Trani and others 2001). In addition, southern wildlife has been influenced by the introduction of exotic species and the overexploitation of native species. Of particular concern is collection of species for the pet trade and overharvest of commercial species (Flather and others 1998). These factors have influenced species and their habitats in different ways.

This chapter provides an overview of the habitat associations of birds, mammals, reptiles, and amphibians in the South. The focus is on vertebrates because information on the regional biogeography of many terrestrial invertebrate groups is lacking (Echternacht and Harris 1993). Additional information on plant and animal associations is provided in chapters 1, 2, and 23.

Taxa groups are described, and general habitat associations for each are summarized. The status, distribution, and habitat requirements are provided for selected species of concern. Finally, conservation and management actions are suggested for enhancing habitat associations and mitigating known threats.

The following sections discuss the conditions needed to maintain and enhance conditions for species that occupy the terrestrial habitats of the South. Scientific names are provided in the chapter tables and the master species list in the Assessment appendix; therefore, only common names are provided in the text.

Methods and Data Sources

Data on the status of threatened or endangered vertebrate species of the South were compiled from the U.S. Department of the Interior (2000). That agency provided information on the distribution of listed species by State. Its recovery plans and other agency publications were used to compile information on life history, ecology, and management of individual species.

Regional species richness in each vertebrate taxon was compiled from State Natural Heritage offices (NatureServe 2000). This database is an inventory of all known occurrences for species of conservation concern. Information was derived from the database to determine geographic patterns of diversity by State in the South. The system was also used to verify the status and distribution of species included in the fauna accounts.

Information on bird habitat associations was obtained from Partners in Flight (2000) conservation plans. These plans highlight the factors that imperil bird species in physiographic areas and recommend management actions. The conservation plans were used to identify species of conservation concern (Pashley and others 2000).

Habitat associations for herpetofauna (reptiles and amphibians) were summarized from the comprehensive review conducted by Wilson (1995). Additional literature reviews and reference materials supplied information on reptile and amphibian ecology.

State agency bear biologists were surveyed for information about the current status, habitat needs, and management concerns about black bears. Nine States responded with information: Alabama, Arkansas, Florida, Kentucky, Mississippi, North Carolina, Oklahoma, Texas, and Virginia.

Information on mammal habitat relationships was compiled from extensive literature searches, field guides, and texts on southern wildlife. Research stations and universities throughout the South were contacted to obtain additional information on selected species.

Results

Birds

The moderate climate and diverse forests across the South support abundant and diverse communities of breeding, wintering, and migrating birds. This vertebrate group comprises 17 major orders and 55 families (Echternacht and Harris 1993). The order Passeriformes dominates the region's avifauna in the number of different families (19) and species (127). These include the flycatchers, crows, swallows, jays, titmice, wrens, vireos, grackles, orioles, finches, sparrows, and warblers among others.

The South supports 595 avian species (NatureServe 2000). The number of bird species ranges from 505 in Texas to 296 in Tennessee. Florida has 419; North Carolina, 390; Oklahoma, 359; and Alabama, 355. These totals include perching birds, shorebirds, wading birds, waterfowl, raptors, and other birds (fig. 5.2).

Perching birds, which include the passerines mentioned above, comprise the majority of bird species. Examples of shorebirds include plovers and curlews, while wading birds include sandhill cranes and flamingos. Mottled ducks, Canada geese, wood ducks, hooded merganser, and mallards represent waterfowl. Eagles, hawks, kites, vultures, and owls are some of the species classified as raptors. The Natural Heritage designation of "other birds" includes gamebirds, such as bobwhite quail, ruffed grouse, American woodcock, wild turkey, and several dove species. This group also includes woodpeckers; open ocean birds such as cormorants, petrels, and pelicans; rails; and many other species.

The coastal wetlands support the greatest number of species. In fact, the South supports the largest number of wading species in the United States (White and others 1998). Thirty-one species occur solely at high elevations in the Appalachian Mountains.

The South also provides habitat for summer breeding populations, birds that overwinter in the region, and birds that migrate to South America. Coastal habitats, maritime forests, and longleaf pine savanna are all important to migrating species.

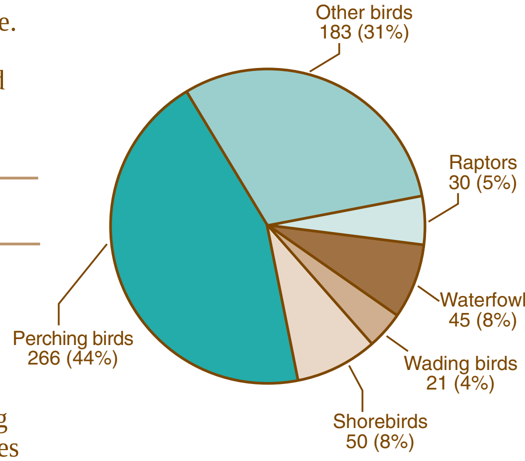

Figure 5.2—Species richness by major subgroups of avian taxa occurring within the South (NatureServe 2000).

Twenty-one species of birds are listed as threatened or endangered (table 5.1). Several of these species inhabit the Coastal Plain. In addition, several birds are classified as imperiled or vulnerable by the Natural Heritage agencies (chapter 1). These species are in jeopardy due to habitat loss, habitat fragmentation, or coastal development (Hall 1995). The dependence on breeding and staging areas has made shorebird populations vulnerable to disturbance. Colonial waterbirds have declined as a result of habitat degradation.

In contrast, the status of other species has improved during the past decade. The status of the brown pelican as well as several species of raptors (ospreys, bald eagles, and peregrine falcons) has improved due to habitat protection and restrictions on the use of DDT (Fuller and others 1995).

There is a substantial body of information on bird-habitat relationships, and extensive long-term monitoring programs have been in place for several decades. The distribution and composition of bird communities is influenced by local habitat and landscape conditions. Local habitat features include forest type, understory, number of foliage layers, canopy structure, and successional stage. Landscape conditions influencing bird populations include patch size, interspersion of vegetative communities, forest fragmentation, edge length, interpatch distance, interior forest, adjacent land use, and spatial heterogeneity.

The following section discusses bird-habitat associations in the South. Species of concern are identified, and recommendations for their management are provided.

Partners in Flight physiographic areas—Partners in Flight (PIF) is an organization formed to promote bird conservation. It is comprised of Federal and State agencies, conservation groups, and forest industry. PIF uses physiographic areas as conservation planning units for evaluating population trends, habitat conditions, land use practices, and emerging conservation issues (fig. 5.3). Boundaries defined by geomorphology, topography, and vegetative communities are based

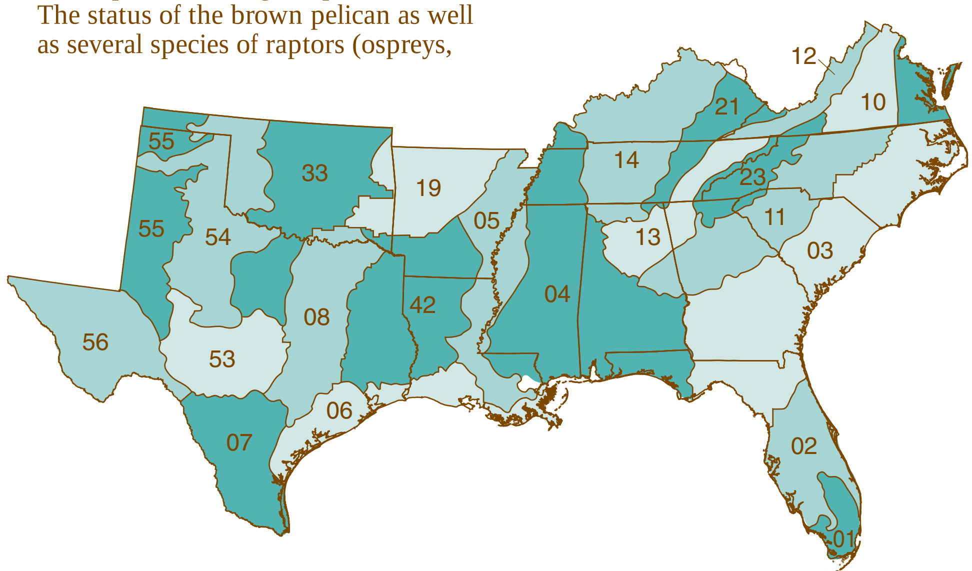

Figure 5.3—The distribution of Partners in Flight physiographic regions within the South (Partners in Flight 2000).

Table 5.1—Bird species in the South that are listed as threatened or endangered

Scientific name	Common name	Areas of occurrence
Wading birds		
Grus americana	Whooping crane (E)	FL, OK, TX
Grus canadensis pulla	Mississippi sandhill crane (E)	MS
Raptors		
Falco femoralis septentrionalis	Northern aplomado falcon (E)	TX
Haliaeetus leucocephalus	Bald eagle (T)	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Polyborus plancus audubonii	Audubon's crested caracara (T)	FL
Rostrhamus sociabilis plumbeus	Everglade snail kite (E)	FL
Shorebirds		
Charadrius melodus	Piping plover (T)	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Mycteria americana	Wood stork (E)	AL, FL, GA, SC
Numenus borealis	Eskimo curlew (E)	OK, TX
Perching birds		
Ammodramus maritimus mirabilis	Cape sable seaside sparrow (E)	FL
Ammodramus savannarum floridanus	Florida grasshopper sparrow (E)	FL
Aphelocoma coerulescens	Florida scrub-jay (E)	FL
Dendroica chrysoparia	Golden-cheeked warbler (E)	TX
Empidonax traillii extimus	Southern willow flycatcher (E)	TX
Vireo atricapillus	Black-capped vireo (E)	LA, MS, OK, TX
Other birds		
Pelecanus occidentalis	Brown pelican (E)	LA, MS, TX
Picoides borealis	Red-cockaded woodpecker (E)	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
Sterna antillarum	Least tern (E)	AR, LA, MS, OK, TN, TX
Sterna dougallii dougallii	Roseate tern (T, E[a])	FL, GA, KY, NC, SC, VA
Strix occidentalis	Spotted owl (T)	TX
Tympanuchus cupido attwateri	Attwater's greater prairie chicken (E)	TX

T = Threatened; E = endangered.
[a] Threatened in the United States where not listed as endangered.
Source: U.S. Department of the Interior (2000).

upon physiographic strata established by the North American Breeding Bird Survey (Peterjohn and others 1995). Physiographic areas are distinguished by having distinct species assemblages, land uses, and conservation issues.

Bird conservation plans prepared for each physiographic area identify species and habitats of conservation concern. Seventeen physiographic areas lie predominately in the South (table 5.2). All of the plans are available online at www.blm.gov/wildlife/pifplans.htm.

The conservation plans prioritize birds of concern and their habitat using several criteria for ranking a species' vulnerability: relative abundance, size of breeding and nonbreeding ranges, threats during breeding and nonbreeding seasons, population trends, and relative density. Numerical scores are given for each criterion, with higher scores reflecting higher vulnerability. Species of concern are represented by scores of 22 and above; these species are the focus of the physiographic area conservation plans.

Table 5.3 presents a summary of the birds of concern for the southern physiographic areas. Species of concern that occur in several physiographic areas include the swallow-tailed kite, red-cockaded woodpecker, Acadian flycatcher, Bell's vireo, brown-headed nuthatch, wood thrush, prairie warbler, cerulean warbler, prothonotary warbler, worm-eating warbler, Swainson's warbler, Louisiana waterthrush, Kentucky warbler, Bachman's sparrow, and Henslow's sparrow. These species and the physiographic areas they inhabit are described below. Management recommendations from the plans follow Pashley and others (2000) unless otherwise cited.

PIF physiographic areas: mid-Atlantic Coastal Plain—This physiographic area extends from the Atlantic Ocean south of Long Island to the Virginia-North Carolina border. The landscape is dominated by forested wetlands, salt marshes, and barrier islands. Upland forests grade from pine-dominated areas on the outer Coastal Plain to hardwood forests on the inland areas. This landscape has been altered by human settlement for approximately four centuries. Human population growth is expected to continue, placing further demands on the region's natural resources.

The mid-Atlantic Coastal Plain supports 185 bird species; 20 (11 percent) are of concern. Among those species, the prairie warbler occupies pine savanna habitat, while the Bachman's sparrow occurs in grassy understories. Salt marshes support important breeding and wintering populations of the black duck, black rail, salt marsh sharp-tailed sparrow, and seaside sparrow. The Acadian flycatcher, cerulean warbler, and prothonotary warbler inhabit forested wetlands. Mixed upland forest supports the wood thrush in well-developed midstories and the worm-eating warbler and Kentucky warbler in dense understories. Henslow's sparrows may also occur along the edges of salt marsh habitat, in areas of regenerating pines, and on former grasslands.

Conservation issues center on managing human population growth while maintaining functioning ecosystems. The extensive forested habitat is heavily fragmented; maintaining blocks large enough to support a diversity of breeding birds is a priority. Protection of critical sites for wintering species must be integrated with conservation plans for breeding habitats. Specific recommendations include restoration of pine savanna conditions through prescribed burning; protection of barrier dunes to minimize losses in species productivity; protection of sites with greater than 125 acres of high marsh; identification of forest areas that support significant populations of prothonotary and cerulean warblers; and the restoration of open lands greater than 125 acres with Henslow's sparrow potential.

PIF physiographic areas: mid-Atlantic Piedmont—The mid-Atlantic Piedmont is separated from the southern Piedmont at the North Carolina-Virginia line. It extends north through Virginia, Maryland, and Pennsylvania before terminating in northern New Jersey. The rolling topography formerly supported extensive hardwood forests including oak-hickory, Appalachian oak, and loblolly-shortleaf pine. Approximately 45 percent of the physiographic area is presently forested, 45 percent is in agricultural production, and the remainder is in urban areas.

The mid-Atlantic Piedmont supports 137 bird species; 11 (8 percent) are of concern. Deciduous and mixed forest habitats support the wood thrush, cerulean warbler, Louisiana waterthrush (in riparian forest buffers), and Kentucky warbler (in dense understory). The shrub-scrub areas and barrens support the bobwhite quail (in decline). The American woodcock (also in decline) requires an interspersion of forest clearings and second-growth hardwoods. Agricultural pastureland supports a large population of grasshopper sparrows and other grassland species.

Table 5.2—Species richness by physiographic area for birds of the South (Partners in Flight 2000)

Physiographic area	State(s)	Total species	Species of concern	
			No.	*%* [a]
01 – Subtropical Florida	FL	103	14	13.2
02 – Peninsular Florida	FL	128	21	15.2
03 – South Atlantic Coastal Plain	FL, GA, SC, NC	161	26	15.5
04 – East Gulf Coastal Plain	FL, AL, MS, LA, TN	161	20	12.2
05 – Mississippi Alluvial Valley	MS, LA, AR	143	17	11.9
06 – Coastal Prairies	LA, TX	168	20	11.5
08 – Oaks and Prairies	TX, OK	147	13	8.7
10 – Mid-Atlantic Piedmont	VA	137	11	8.0
11 – Southern Piedmont	AL, GA, SC, NC	125	14	11.2
12 – Mid-Atlantic Ridge and Valley	VA	166	14	8.4
13 – Southern Ridge and Valley	AL, GA, TN	131	21	16.0
14 – Interior Low Plateaus	AL, TN, KY	159	15	9.4
19 – Ozark-Ouachita Plateau	AR, OK	151	17	11.2
21 – Northern Cumberland Plateau	AL, TN, KY, VA	144	18	12.5
23 – Southern Blue Ridge	GA, SC, NC, VA	156	20	12.8
42 – West Gulf Coastal Plain	LA, AR, TX, OK	130	18	13.8
44 – Mid-Atlantic Coastal Plain	VA	185	20	10.6

[a] Species of concern represented by scores of 22 and above.

Table 5.3—Bird species of concern in the South (Partners in Flight 2000)

Scientific name	Common name	Physiographic areas[a]
Egretta rufescens	Reddish egret	02, 04, 08
Eudocimus albus	White ibis	01, 02
Anas rubripes	American black duck	44
Anas fulvigula	Mottled duck	01, 02, 06
Elanoides forficatus	Swallow-tailed kite	01, 02, 04, 05, 06, 08, 42
Rostrhamus sociabilis	Snail kite	01, 02
Buteo brachyurus	Short-tailed hawk	01, 02, 03
Tympanuchus cupido	Greater prairie chicken	06, 08
Colinus virginianus	Northern bobwhite	03, 04, 08, 11
Laterallus jamaicensis	Black rail	02, 03, 08, 44
Rallus longirostris	Clapper rail	02, 03, 06
Grus Canadensis	Sandhill crane	02
Charadrius alexandrinus	Snowy plover	02
Charadrius wilsonia	Wilson's plover	02, 03, 06
Charadrius melodus	Piping plover	03, 44
Haematopus palliatus	American oystercatcher	02, 03, 04, 08
Sterna forsteri	Forster's tern	06
Columba leucocephala	White-crowned pigeon	01
Coccyzus americanus	Yellow-billed cuckoo	04, 05, 08, 13, 14, 42
Coccyzus minor	Mangrove cuckoo	02
Caprimulgus carolinensis	Chuck-will's-widow	04, 13, 42
Caprimulgus vociferus	Whip poor will	10, 11, 12, 14
Chaetura pelagica	Chimney swift	14
Amazilia yucatanensis	Buff-bellied hummingbird	06
Picoides borealis	Red-cockaded woodpecker	01, 02, 03, 04, 11, 13, 19, 21, 23, 42, 44
Campephilus principalis	Ivory-billed woodpecker	03
Contopus virens	Eastern wood-pewee	12, 44
Empidonax virescens	Acadian flycatcher	10, 13, 19, 21, 23, 44
Tyrannus dominicensis	Gray kingbird	01, 02
Tyrannus forficatus	Scissor-tailed flycatcher	06, 08, 42
Lanius ludovicianus	Loggerhead shrike	02
Vireo griseus	White-eyed vireo	05, 42
Vireo bellii	Bell's vireo	04, 05, 06, 08, 14, 19, 42
Vireo flavifrons	Yellow-throated vireo	12, 13, 21, 23, 44
Vireo altiloquus	Black-whiskered vireo	01, 02
Aphelocoma coerulescens	Florida scrub-jay	01, 02, 03
Tachycineta cyaneoviridis	Bahama swallow	01
Petrochelidon fulva	Cave swallow	01, 06, 08
Sitta pusilla	Brown-headed nuthatch	02, 03, 04, 05, 10, 11, 13, 19, 23, 42, 44
Thryomanes bewickii	Bewick's wren	11, 12
Hylocichla mustelina	Wood thrush	03, 05, 10, 12, 13, 19, 21, 23, 44
Toxostoma longirostre	Long-billed thrasher	06
Vermivora bachmanii	Bachman's warbler	03, 04, 05
Vermivora pinus	Blue-winged warbler	05, 13, 14, 44
Vermivora chrysoptera	Golden-winged warbler	12, 13, 21, 23
Parula americana	Northern parula	03, 05, 12
Dendroica pensylvanica	Chestnut-sided warbler	23
Dendroica caerulescens	Black-throated blue warbler	04, 05, 12, 13, 21, 23
Dendroica fusca	Blackburnian warbler	23
Dendroica dominica	Yellow-throated warbler	03, 13, 23
Dendroica discolor	Prairie warbler	01, 03, 04, 10, 11, 12, 13, 14, 19, 21, 23, 42, 44

continued

Table 5.3—Bird species of concern in the South (Partners in Flight 2000) (continued)

Scientific name	Common name	Physiographic areas[a]
Dendroica cerulea	Cerulean warbler	03, 04, 05, 10, 11, 12, 13, 14, 19, 21, 23, 42, 44
Mniotilta varia	Black-and-white warbler	23
Protonotaria citrea	Prothonotary warbler	03, 04, 05, 06, 11, 13, 19, 21, 42, 44
Helmitheros vermivorus	Worm-eating warbler	03, 04, 05, 08, 10, 11, 12, 13, 14, 19, 21, 23, 42, 44
Limnothlypis swainsonii	Swainson's warbler	03, 04, 05,06, 08, 11, 12, 13, 14, 19, 21, 23, 42, 44
Seiurus motacilla	Louisiana waterthrush	12, 13, 14, 19, 21, 23, 42
Oporornis formosus	Kentucky warbler	04, 05, 06, 10, 11, 13, 14, 19, 21, 23, 42, 44
Wilsonia citrina	Hooded warbler	03, 21, 23, 42
Wilsonia canadensis	Canada warbler	23
Piranga rubra	Summer tanager	21
Aimophila aestivalis	Bachman's sparrow	02, 03, 04, 06, 10, 11, 13, 14, 19, 21, 23, 42, 44
Spizella pusilla	Field sparrow	10, 11, 13, 14, 19, 21
Ammodramus henslowii	Henslow's sparrow	03, 06, 10, 11, 12, 14, 19, 21, 44
Ammodramus caudacutus	Saltmarsh sharp-tailed sparrow	03, 44
Ammodramus maritimus	Seaside sparrow	01, 02, 03, 04, 06, 44
Passerina ciris	Painted bunting	03, 05, 06, 08, 19
Spiza americana	Dickcissel	06, 14, 19
Icterus spurius	Orchard oriole	04, 05, 13, 42
Icterus graduacauda	Audubon's oriole	06

[a] Physiographic areas: 01 – Subtropical Florida, 02 – Peninsular Florida, 03 – South Atlantic Coastal Plain, 04 – East Gulf Coastal Plain, 05 – Mississippi Alluvial Valley, 06 – Coastal prairies, 08 – Oaks and prairies, 10 – Mid-Atlantic Piedmont, 11 – Southern Piedmont, 12 – Mid-Atlantic Ridge and Valley, 13 – Southern ridge and valley, 14 – Interior Low Plateaus, 19 – Ozark-Ouachita Plateau, 21 – Northern Cumberland Plateau, 23 – Southern Blue Ridge, 42 – west Gulf Coastal Plain, and 44 – Mid-Atlantic Coastal Plain.

Conservation issues center on the management of human population growth and protection of conservation areas. Enhancement of grassland habitat also is a priority. Specific recommendations include management of areas that support significant populations of cerulean and Kentucky warblers, restoration of natural barrens that support shrub-nesting species, and monitoring priority species in disturbed areas.

PIF physiographic areas: mid-Atlantic Ridge and Valley—This physiographic area extends from western Maryland through the mountains of Virginia. Consisting of mountain ridges and intervening valleys, the predominant forest type is oak-hickory. Relict patches of spruce-fir occur on high mountain ridges. Agricultural production and urban development dominate in the lower valleys. Human populations are relatively sparse and confined to the valleys, while coal extraction occurs on public and private forests. Disease and insect pests are important disturbance factors; the pesticides used for gypsy moth control impact other foliage insects that are important bird food (Hunter and others 2001).

The mid-Atlantic Ridge and Valley supports 166 bird species; 14 (8 percent) are of concern. Early successional shrub habitat (including barrens and disturbed sites) supports the whippoorwill, golden-winged warbler, and prairie warbler. The wood thrush and worm-eating warbler occupy mature deciduous forest, while the Louisiana waterthrush is found in late successional stands near streams. The black-throated blue warbler and the blackburnian warbler use northern hardwood and spruce-fir forests.

Conservation issues center on long-term planning on public land to meet the habitat needs of species requiring specific seral stages. On public land, it is important to balance the needs of early successional species with those requiring mature forest (Trani and others 2001). Specific actions needed for this physiographic area include management of high-elevation spruce-fir habitat, intensive surveys for Appalachian Bewick's wren, identification of breeding sites for golden-winged warbler, and the maintenance of composition and structural diversity.

PIF physiographic areas: northern Cumberland Plateau—The Cumberland Plateau is a predominantly forested, gently rolling tableland bordered by the eastern rim of the Interior Low Plateaus and the Cumberland Mountains (fig. 5.3). The area includes eastern Kentucky and Tennessee, southwestern West Virginia, and a small area in western Virginia. Forests dominated by oaks and hickories are common. Various pine species are dominant on drier sites.

The northern Cumberland Plateau supports 144 bird species; 18 (12 percent) are of concern. Among species of concern, the Acadian flycatcher, wood thrush, worm-eating warbler, and Swainson's warbler inhabit mixed mesophytic forests. Coniferous forests support the red-cockaded woodpecker (low-elevation yellow pine) and Bachman's sparrow. Bewick's wren and golden-winged warbler use early successional habitat, while Henslow's sparrow occurs in grassland areas. Both habitats exist only due to disturbance.

Conservation issues center on the maintenance of species composition and vegetation structure. Widespread timber harvesting and fire suppression have reduced both old-growth and young forest habitats. The current structure of the mid-seral forest may not be optimal for many midstory and understory breeding birds. As a result of diminishing habitat quality, several high-priority birds have undergone significant population declines. The northern Cumberland Plateau is one of the most heavily forested physiographic areas in the South. Specific recommendations include management of 12 to 15 percent of forests for long-rotation sawtimber or old growth, increased use of fire in low-elevation yellow pine habitat, and maintenance of shrub-scrub conditions.

PIF physiographic areas: southern Ridge and Valley—This physiographic area includes the southern end of the Ridge and Valley and the tablelands of the southern Cumberland Plateau. It is in eastern Tennessee, northwest Georgia, and northeast Alabama. The upland forest is predominantly in oak-hickory and pine (shortleaf or loblolly) types.

The southern Ridge and Valley supports 131 bird species; 21 (16 percent) are of concern. Early successional scrub-shrub habitat is occupied by the Bewick's wren, blue-winged warbler, and orchard oriole. The hardwood forest component supports the Acadian flycatcher, yellow-throated warbler, prothonotary warbler, worm-eating warbler, and Swainson's warbler among others. Red-cockaded woodpeckers and brown-headed nuthatches are found in southern pines.

Conservation issues focus on the conversion of hardwood forest to monocultures of loblolly pine. A large percentage of natural vegetation has been cleared for agriculture and urban development. Birds dependent on mature forest may be at risk because the amount of public land may not be sufficient to support viable populations of sensitive species (Hunter and others 2001). Enhancement of habitat for these species will require the use of long-rotation harvests. Specific recommendations include expansion of longleaf habitat using prescribed fire and the enhancement of scrub habitat.

PIF physiographic areas: southern Blue Ridge—The Southern Blue Ridge runs along the border between Tennessee and North Carolina, extending into South Carolina, Georgia, and Virginia. The area is comprised of rugged mountains, broad ridges, steep slopes, and deep ravines. Spruce-fir forests at the highest elevation transition into northern hardwoods, hemlock-white pine, and Appalachian oaks at lower elevations. Cove forests occur on mesic sites, while fire-associated yellow pines occur on dry ridges. Disturbances from fire, grazing, and storms are primary factors in determining forest composition and structure.

The southern Blue Ridge supports 156 bird species; 20 (13 percent) are of concern. Among species of concern, the northern saw-whet owl, black-capped chickadee, red-breasted nuthatch, golden-crowned kinglet, red crossbill, and yellow-bellied sapsucker are distinct subspecies whose ranges are centered within the southern Blue Ridge. With the exception of the sapsucker, each species occupies high forested peaks. The yellow-bellied sapsucker, as well as the golden-winged warbler, inhabits disturbed forest areas. Among species of concern requiring mature forest in the southern Blue Ridge are Acadian flycatchers, yellow-throated vireos, wood thrushes, blackburnian warblers, Swainson's warblers, Kentucky warblers, and Canada warblers.

Conservation issues include population declines of both migrant and resident birds. The rapid construction of new homes and associated developments along roads contribute to habitat loss and fragmentation. Another concern is the decline of high-elevation spruce-fir forests resulting from exotic pests and reduced air quality. Atmospheric pollution is reducing tree growth, insectivore food availability, and supplies of important minerals necessary for successful bird reproduction (Hunter and others 2001).

Many species in this habitat are in isolated endemic populations that may be genetically distinct from populations elsewhere. Populations of priority birds, such as the Appalachian subspecies of Bewick's wren, have declined in recent years. Maintenance of early successional habitat is a conservation need. Other recommendations include management of riparian zones and the provision of old-growth forest.

PIF physiographic areas: southern Piedmont—This physiographic area extends through central North Carolina, South Carolina, and Georgia into eastern Alabama. Plains, hills, tablelands, and numerous rivers characterize the Piedmont. The area lies between the Appalachian Mountains and the Coastal Plain. The dominant vegetation includes oak-hickory and mixed hardwood forests. Shortleaf, loblolly, and scattered longleaf pines are prevalent on disturbed sites.

The southern Piedmont supports 125 bird species; 14 (11 percent) are of concern. Among species of concern, the prairie warbler, Bachman's sparrow, and Henslow's sparrow are supported by grassland and shrub habitat. Southern pine forests support the red-cockaded woodpecker and brown-headed nuthatch, while prothonotary and Swainson's warblers use the bottomland hardwoods. Upland hardwood habitat supports the whippoorwill, wood thrush, and cerulean warbler.

Conservation challenges focus on human population growth, urban sprawl, and the intensification of agriculture and timber harvesting. Several bird populations have declined in patches of protected mature forests embedded in suburban settings. In addition, changing land use has resulted in a loss of early successional habitat. Public lands provide core areas in the Piedmont on which to manage habitat. The maintenance of bird communities requires coordination among public agencies, forest industry, and private landowners.

PIF physiographic areas: south Atlantic Coastal Plain—The south Atlantic Coastal Plain covers northeastern Florida, southern Georgia, the eastern Carolinas, and the Great Dismal Swamp in Virginia. Coastal areas contain barrier islands, maritime forests, marshland, and estuaries. Inland areas support bottomland hardwood forests, pocosins, and

Carolina bays. Fire-maintained forests of longleaf, shortleaf, and loblolly pine once dominated upland areas.

The south Atlantic Coastal Plain supports 161 bird species; 26 (15 percent) are of concern. Among species of concern, the American kestrel, red-cockaded woodpecker, and brown-headed nuthatch require pine forest, and Henslow's sparrow requires pocosin grasslands. The swallow-tailed kite, northern parula, Swainson's warbler, and hooded warbler occupy bottomland and upland hardwood forests. The prairie warbler and painted bunting are found in the scrub-shrub habitat.

Conservation concerns include fire management, land conversion, and short-rotation pine plantations. Restoration of fire-maintained pine savanna benefits pine-grassland species, particularly the red-cockaded woodpecker. Pine plantations are used by other species, but the maintenance of age class diversity is important. Other recommendations include maintenance of large tracts of bottomland forest in river systems to benefit black-throated green warblers and breeding swallow-tailed kites, and retention of coastal maritime forest and scrub-shrub habitats for the bunting and in-transit migrants.

PIF physiographic areas: peninsular Florida—This physiographic area extends from the northern edge of Lake Okeechobee in central Florida to the Suwanee River in northern Florida. Habitat includes sandhill, scrub, and xeric hammock communities. Longleaf pine, turkey oak, and wiregrass characterize the fire-dependent sandhill communities. Dominant scrub vegetation includes sand pine and scrub oak. Xeric hammocks support live oak, laurel oak, and saw palmetto. Upland hardwoods, wetlands, and mangroves are also locally common to abundant in the physiographic area.

Peninsular Florida supports 128 bird species; 21 (15 percent) are of concern. Among species of concern, crested caracara (threatened), burrowing owl, Florida scrub jays (endangered), and grasshopper sparrows inhabit the scrub and grassland habitat. Wetland and mangrove habitats support the swallow-tailed kite, snail kite (endangered), and short-tailed hawk. The painted bunting occurs in maritime scrub, while the American kestrel, red-cockaded woodpecker, and Bachman's sparrow use pine forests.

Conservation actions are directed at fostering cooperative relations with private landowners, and encouraging proper habitat management through education, tax breaks, and conservation easements. Conservation goals also include the public acquisition of acreage in sandhills, oak scrub, upland forest, and floodplain swamp communities.

PIF physiographic areas: subtropical Florida—This physiographic area extends south from Lake Okeechobee in central Florida to the Florida Keys. The tropical ecosystem contains the Everglades and the Big Cypress Reserve. Fire is an important feature in the pine, marsh, and prairie communities. Hurricane disturbances create early successional habitat. Distinct dry and wet seasons influence the nesting cycles of many birds.

Subtropical Florida supports 103 bird species; 14 (13 percent) are of concern. Pine rocklands, flatwoods, and sand scrub habitats are used by the Florida scrub jay, sedge wren, and palm warbler. Grassland and dry prairie communities support the sandhill crane and grasshopper sparrow. The short-tailed hawk, white-crowned pigeon, and gray kingbird inhabit subtropical deciduous forests. The reddish egret, white ibis, wood stork, seaside sparrow, and several species of rails use the brackish saltwater and freshwater marsh habitats of the Everglades. Mangrove swamps support the mangrove cuckoo, the black-whiskered vireo, and the Cuban subspecies of the yellow warbler.

Conservation concerns are directed towards the rapidly growing human population in the region. Habitats have been lost by converting land to urban and agricultural uses, such as sugarcane and citrus production. Other problems include pollution and alteration of the hydroperiod and natural water cycles. Recommendations include aggressive acquisition programs and the maintenance of pine-dominated stands and prairies through prescribed burning. Programs for bird conservation were created by the Surface Water Improvement and Management Act, Florida's Everglades Forever Act, and the South Florida Ecosystem Restoration Task Force.

PIF physiographic areas: Interior Low Plateaus—The Interior Low Plateaus extend from Alabama northward across central Tennessee and Kentucky into southern Illinois, Indiana, and Ohio, encompassing the central basin and Tennessee Valley. Oak-hickory and beech-maple forests were historically the most abundant cover types. There were also tallgrass prairies and oak savannas in the northern section. Barrens and glades are rare in the central regions, and forested wetlands occur along major waterways.

The Interior Low Plateaus support 159 bird species; 15 (9 percent) are of concern. Priority species inhabiting hardwood forest include the whippoorwill, cerulean warbler, and Louisiana waterthrush. The grassland, savanna, and old-field habitats support the Bewick's wren, blue-winged warbler, and dickcissel.

Conservation issues center on habitat loss from land conversion, habitat deterioration, and fragmentation. Pastureland has replaced grassland and savanna, while glades and barrens have become urban areas. Fire suppression has allowed woody vegetation to encroach into open areas. Floodplain forests have been converted to reservoirs or row crops. Previous forest management and chipping of all woody vegetation have influenced canopy characteristics, understory development, and age structure of upland forests.

Specific recommendations include the reestablishment of greater prairie chicken and swallow-tailed kite populations, maintenance of existing forested acreage, and the restoration of forested wetlands, warm season grasses, and oak savannas.

PIF physiographic areas: Ozarks and Ouachitas—The Ozark Mountains extend from southern Missouri into northern Arkansas and consist of dissected plateaus covered by oak forest with glade and savanna inclusions. The ridge and valley system of the Ouachitas covers central Arkansas, reaching into eastern Oklahoma. Vegetation includes shortleaf pine and deciduous forests. The vegetation changes to prairie in the northern reaches.

The Ozarks and Ouachitas support 151 bird species; 17 (11 percent) are of concern. Deciduous and mixed forest habitat supports the whippoorwill, worm-eating warbler, and Kentucky warbler. The red-cockaded woodpecker and Bachman's sparrow occur in pine savanna; populations of both species have declined dramatically due to fire exclusion and forestry practices. The Bewick's wren and the field sparrow use early successional habitat; both species are undergoing significant declines.

Conservation actions include the improvement of shortleaf pine, glade, and savanna communities through the use of thinning, overstory removal, and dormant season burns. Other activities include the prevention of forest fragmentation stemming from urbanization and the management of habitat required by early successional species.

PIF physiographic areas: East Gulf Coastal Plain—The East Gulf Coastal Plain extends from Louisiana and western Florida northwards through Mississippi and Alabama into Tennessee and Kentucky. Numerous streams and rivers break the rolling topography. Uplands are dominated by shortleaf pine and mixed hardwoods. Loblolly pine and bottomland hardwood forests occur in the lowland areas.

The East Gulf Coastal Plain supports 161 bird species; 20 (12 percent) are of concern. Swallow-tailed kites, prothonotary warblers, and Kentucky warblers occur in the forested wetlands and other habitat. The northern bobwhite, Mississippi sandhill crane (endangered), red-cockaded woodpecker, and sedge wren occupy the pine and savanna habitats. Chuck-will's-widow occurs in upland hardwoods, while the LeConte's sparrow and orchard oriole are present in the scrub habitat. Numerous spring migrants use the maritime forests. Emergent wetlands support the reddish egret, yellow and black rails, and Nelson's sharp-tailed sparrow. Snowy, piping, and Wilson's plovers inhabit the beach dunes community.

Conservation issues include the conversion of longleaf pine and upland hardwoods to other species, hydrological alteration, land use changes including coastal development, and the changes in species composition and structure resulting from fire suppression. Specific recommendations include maintenance of large tracts of longleaf pine and upland hardwoods for red-cockaded woodpeckers, swallow-tailed kite, cerulean warbler, Swainson's warblers, and associated species. Other actions include the control of exotic plants and the restoration of maritime forest, emergent wetlands, and beach dunes that are important to priority breeding and wintering birds.

PIF physiographic areas: Mississippi Alluvial Valley—Encompassing the floodplain of the Mississippi River, the valley includes eastern Louisiana, eastern Arkansas, northwestern Mississippi, and portions of Tennessee, Kentucky, and Missouri. The South's biggest concentration of bottomland hardwoods is in the Mississippi River Valley, where agricultural conversion has resulted in forest fragmentation. The Mississippi River and its flood regimes, which influence vegetation communities and bird habitat conditions, shape this physiographic area.

The Mississippi Alluvial Valley supports 143 bird species; 17 (12 percent) are of concern. Among species of concern, the swallow-tailed kite, northern parula, and painted bunting are supported by bottomland hardwood forests. Marsh, wetland, and open land support several species of shorebirds and waterfowl and provide important wintering areas for mallards, wood ducks, and other birds.

Conservation recommendations target the restoration of bottomland hardwood forest to support healthy populations of a suite of birds. Since settlement, over 80 percent of the forest has been cleared for agriculture and other uses. The hydrology has been dramatically altered, inhibiting ecosystem functions. The resulting forest fragmentation has reduced the ability of the area to support many bird populations. The Lower Mississippi Valley Joint Venture leads restoration efforts (Pashley and others 2000).

PIF physiographic areas: West Gulf Coastal Plain—The West Gulf Coastal Plain is located in northwestern Louisiana, southwestern Arkansas, eastern Texas, and southern Oklahoma. The physiographic area is characterized by loblolly pine, shortleaf pine, and longleaf pine forests on the uplands, hardwood forests in the bottomlands, and grasslands in the southernmost areas.

The West Gulf Coastal Plain supports 130 bird species; 18 (14 percent) are of concern. Among such species, the American kestrel, chuck-will's-widow, scissor-tailed flycatcher, brown-headed nuthatch, Bewick's wren, prairie warbler, and Bachman's sparrow are supported by pine forests and associated grasslands. The swallow-tailed kite, white-eyed vireo, worm-eating warbler, Swainson's warbler, and hooded warbler occupy hardwood forests and other supported habitats. The bottomland forests and riparian habitats are important for stopover migrants.

Conservation issues include fire suppression and regeneration practices that have replaced native species with loblolly or slash pine. Although many bird species occur in young pine plantations, others such as the red-cockaded woodpecker require native pine savanna conditions or mature longleaf pine stands. Specific recommendations include the maintenance of mature longleaf pine stands with fire, prevention of additional forest conversion to agricultural uses, and deterrence of bottomland hardwood loss due to inundation by reservoirs. The importance of these hardwoods for area-sensitive species and spring migrants extends beyond the West Gulf Coastal Plain.

PIF physiographic areas: oaks and prairies—This physiographic area extends from the Red River of Oklahoma southward into Texas. Tallgrass prairie, post-oak savanna, bottomland hardwood forests, riparian forests, and upland hardwood forests associated with dense scrub layers characterize the area. Wetlands and freshwater marshes are associated with streams, rivers, and reservoirs.

The oaks and prairies support 147 bird species; 13 (9 percent) are of concern. Among such species, the greater prairie chicken, northern bobwhite, scissor-tailed flycatcher, Bell's vireo, and painted bunting are supported by grassland and scrub habitats.

Conservation issues focus on the loss of prairie habitat. Areas of tallgrass prairie have been converted to crop production; less than 10 percent of original prairie exists. The continued loss of tallgrass habitat inhibits restoration efforts by reducing genetic diversity; preservation of remaining habitat is critical. Encroachment by heavy woody growth and exotic species also causes loss of grassland habitat. Prescribed fire and grazing management through incentive programs are beneficial.

PIF physiographic areas: coastal prairies—This physiographic area is found along the Gulf Coast shoreline in Louisiana and Texas. The area supports a complex of marshes, upland grassland, and forested habitat. Marsh communities include salt, brackish, and freshwater marsh. The majority of grassland habitats have been converted to pasture and rice farms. Forested areas occur along major rivers, beach-front ridges, salt domes, and manmade levees. These woodlands are comprised of hackberry and live oak, while the bottomland hardwood forests contain the cypress-tupelo, hackberry-ash-elm, and oak-willow forest types.

The coastal prairies support 168 bird species; 20 (11 percent) are of concern. Priority grassland birds include the greater prairie chicken, short-eared owl, sedge wren, and Sprague's pipit. The bottomland hardwood forest supports the swallow-tailed kite, American woodcock, prothonotary warbler, and Swainson's warbler. Bell's vireo and painted bunting occupy scrub-shrub habitat. In addition, many passerine species use the coastal habitat during spring migration.

Conservation concerns focus on the alteration of natural communities in the coastal prairies. Oil and gas development, dredging, and impoundments have degraded marsh habitat. Grazing animals have degraded grassland and woodland areas. Specific recommendations include cooperative management with private landowners, incentive programs, and identification of potential habitat for priority birds. Other actions include marsh restoration, retention of forested wetlands, exotic species control (especially Chinese tallow), and monitoring the influence of rice crop conversion on waterbird species.

Additional information on the habitat associations of bird species in the South can be found in Hunter and others (2001) and Hamel (1992). The physiographic associations for nonbird taxa are not as well developed as those presented above for birds. Therefore, the habitat needs of mammals, reptiles, and amphibians will be discussed by broad taxonomic grouping.

Amphibians

Two orders of amphibians are present in the Southern United States: Caudata (salamanders) and Anurans (frogs and toads). The South supports the highest density of amphibian species in North America (Echternacht and Harris 1993). The total includes 107 salamanders and 63 species of frogs and toads (fig. 5.4). In individual States, the number of amphibian species ranges from 80 in North Carolina to 49 in Arkansas (NatureServe 2000). Numbers in other States are 77 in Georgia, 75 in Texas, 73 in Virginia, and 70 in Tennessee.

The Southern Appalachians have an unusually large number of salamander species, because many plethodontid species evolved there. These lungless animals are believed to have evolved in fast-flowing, oxygenated streams. The numbers of salamanders inhabiting North Carolina (50), Virginia (48), Tennessee (48), and Georgia (44) reflect the importance of the Appalachian Mountains. The number of salamanders occurring in the Coastal Plain is lower because habitat and temperature are less suitable and because densities of terrestrial and aquatic predators are higher (Echternacht and Harris 1993).

Numbers of frogs and toads are highest in the southernmost Coastal States. Numbers of species are 43 in Texas, 33 in Georgia, 32 in Florida, 31 in Louisiana, 31 in South Carolina, and 30 in Alabama (NatureServe 2000). The majority of southern species are in five families: true frogs; tree, chorus, and cricket frogs; true toads; narrowmouth toads; and spadefoot toads. Eleven species are endemic to the South (Echternacht and Harris 1993).

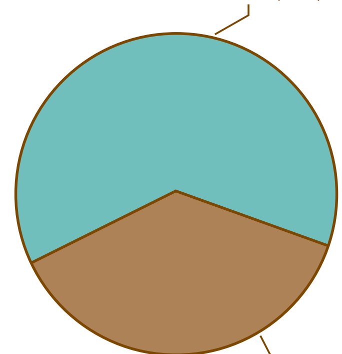

Figure 5.4—Species richness by major subgroups of amphibian taxa occurring within the South (NatureServe 2000).

Table 5.4—Amphibian species in the South that are listed as threatened or endangered

Scientific name	Common name	Areas of occurrence
Frogs and toads		
Bufo houstonensis	Houston toad (E)	TX
Salamanders		
Ambystoma cingulatum	Flatwoods salamander (T)	AL, FL, GA, SC
Eurycea nana	San Marcos salamander (T)	TX
Eurycea sosorum	Barton Springs salamander (E)	TX
Phaeognathus hubrichti	Red Hills salamander (T)	AL
Plethodon shenandoah	Shenandoah Mountain salamander (E)	VA
Tyhplomolge rathbuni	Texas blind salamander (E)	TX

Source: U.S. Department of the Interior (2000).

Seven species of amphibians are listed as threatened or endangered by the U.S. Fish and Wildlife Service (table 5.4). In addition, several amphibians are classified as imperiled or vulnerable by the Natural Heritage agencies (chapter 1).

Amphibians have complex life cycles and inhabit a variety of environments. Habitats include ephemeral pools, caves, forests, wetlands, savannas, and several aquatic habitats. The longleaf pine-wiregrass community, cypress-gum swamps, isolated wetlands, and mixed hardwood-pine habitats support a diversity of species. The federally listed flatwoods salamander is found in the longleaf pine-wiregrass ecosystem. Coastal Plain forests provide habitat for ambystomatid species. In even greater abundance in the South are the many species of tree frogs, toads, and other frogs. Pine barrens tree frogs occur in Coastal Plain forests from Alabama northwards (Gibbons and Buhlmann 2001).

Amphibians are very different physiologically from reptiles, but the two groups are classified together as herpetofauna. Amphibians are more restricted by environmental moisture than other terrestrial vertebrates. They depend on areas where there is sufficient moisture for reproduction and survival. Since the glandular thin skin of amphibians is permeable to water, evaporative water loss is a serious problem. In addition, drought affects egg laying and larvae survival. The demands of water balance and thermoregulation may restrict movement, which occurs in a narrow range of environmental conditions.

Many amphibian species have geographic ranges that are restricted to particular physiographic regions. Some salamander species are considered glacial relicts that were isolated on mountaintops that retained northern climates (Gibbons and Buhlmann 2001). Similarly, frog species such as the pine barrens tree frog, Houston toad, and Florida bog frog occur in small, isolated populations throughout their ranges. The distances between such disjunct populations make recolonization difficult.

Salamanders—The majority of southern salamanders are in six families: mole salamanders, amphiumas, hellbenders, lungless salamanders, waterdogs or mudpuppies, and sirens. Salamanders are inconspicuous species that are important components of the forest ecosystem. They are small, secretive, and primarily nocturnal. They range from 5 cm to over 1 m in length. Limited data suggest that generation times are relatively long. For example, the generation times for several species of salamanders range between 4.4 and 9.5 years.

The rate of reproduction in amphibians is highly variable, but many species exhibit low frequencies of reproduction. Often salamanders breed only in alternate years, when they lay a single clutch of eggs.

Moisture is a limiting factor for all salamander species. Some species are totally aquatic, but even the terrestrial species can only survive in moist microhabitats. *Ambystoma* and *Hemidactylus* salamanders require moist, friable soils for burrowing. Several terrestrial species migrate to aquatic habitats for egg deposition, while others require damp microhabitats. In addition, some aquatic species use terrestrial habitat for dispersal and other seasonal activity.

Salamanders inhabit areas with a variety of physiographic features, but rivers, streams, and stream margins figure prominently in their occurrence (table 5.5). Coastal bayous, ponds, and slow-moving rivers support sirens and amphiumas, while the hellbender occurs in cooler, fast-flowing upland rivers.

Table 5.5—The relationships of amphibians to physiographic features and other habitat elements[a]

Forest cover types	Salamanders		Frogs and toads	
	No.	*%*	*No.*	*%*
Physiographic feature				
Sandhills	3	3	8	20
Flatwoods	12	13	12	30
Narrow stream margins	29	32	3	8
Broad stream margins	22	24	20	50
Swamps	16	17	17	43
Cypress strands	10	11	5	13
Cypress ponds	14	15	12	30
Cypress drains	13	14	9	23
Willow heads	11	12	9	23
Bays and pocosins	15	16	14	35
Rivers and streams	34	37	9	23
Permanent ponds	8	9	20	50
Vernal ponds	16	17	27	68
Lakes	9	15	13	33
Specific requirement				
Closed canopy	76	83	11	28
Open canopy	12	13	32	80
Shrub thickets	0	0	8	20
Moist soil	69	75	25	63
Sandy or friable soils	5	5	18	45
Leaf litter	75	82	22	55
Snags	0	0	2	5
Fallen logs	70	76	5	13
Rock outcrops	8	9	1	3
Crevices and/or caves	11	12	0	0
Seepages	23	25	12	30
Potholes	12	13	22	55
Aquatic rocks and/or logs	30	33	0	0
Aquatic vegetation	10	11	26	65

[a] Data are summarized from species accounts presented in Wilson (1995).

Leaf litter, fallen logs, moist soils, and other surface debris serve as refuges from drying conditions. The ringed and streamside salamanders use moist soil, while the flatwoods and Jefferson salamanders use leaf litter. Fallen logs provide an important habitat component for the marbled and mole salamanders. Several species, including the spotted and Mabee's salamanders, also prefer closed-canopy conditions adjacent to water sources.

Table 5.6 shows the associations between 23 vegetative cover types (following Hamel 1992) and salamanders in the South. Mesic, mixed pine, and hardwood forests support 72 percent of species, including ringed, marbled, and mole salamanders. Sixty-four percent of the salamanders occupy mesic, upland hardwoods. These species include streamside, smallmouth, seepage, and dusky salamanders. White pine-hemlock and bottomland forests are used by slightly less than half of the southern salamanders. Jefferson, spotted, and green salamanders occupy white pine-hemlock forests, while several amphiuma species are found in bottomland hardwood forests. Xeric oak-hickory forests also support a variety of salamanders.

Salamander diversity appears to be less on the Coastal Plain than in the Appalachian Mountains. The former has much sandy, well-drained soil, high summer temperatures, and higher densities of predators (Echternacht and Harris 1993).

Connectivity between preferred forest habitats reduces population isolation and promotes dispersal (Wilson 1995), a management concern for many amphibian species. Many salamanders are adapted to travel only short distances in response to habitat alteration, while others with restricted geographic ranges become imperiled if habitat modification is rapid enough to preclude dispersal to similar habitats (Gibbons and Buhlmann 2001).

Table 5.7 illustrates relationships between salamander occurrence and forest successional stage. The seral stages follow those used by Hamel (1992): grass-forb, seedling-sapling, poletimber, and sawtimber. Note that not all cover types contain each seral stage. The Everglades type, for example, only exists in the grass-forb stages.

Table 5.6—The relationship between forest cover type and amphibian occurrence in the South[a]

Forest cover types	Salamanders		Frogs and toads	
	No.	*%*	*No.*	*%*
Everglades	4	4	9	23
Tropical hardwoods	0	0	14	10
Longleaf-slash pine	6	7	14	35
Pine-flatwoods	9	10	19	48
Virginia-pitch pine (xeric upland pines)	19	21	10	25
Longleaf pine	7	8	22	55
Loblolly-shortleaf pine	28	30	15	38
White pine-hemlock	43	47	10	25
Pond pine	5	5	14	35
Longleaf-scrub oak	2	2	8	20
Mixed, pine-hardwood (mesic)	66	72	33	83
Mixed, pine-hardwood (xeric)	0	0	22	55
Spruce fir	10	11	0	0
Upland hardwoods (mesic)-white oak-red oak	59	64	19	48
Cypress tupelo	26	28	22	55
Bottomland hardwoods-(sweetgum-willow oak)	43	47	31	78
Sweetgum–yellow-poplar	30	33	20	50
Bay-pocosin	20	22	22	55
Live oak (maritime)	6	7	12	30
Maple-beech	24	26	9	23
Cove hardwoods	29	32	7	18
Spartina	0	0	4	10
Elm-ash	1	1	4	10
Oak-hickory (xeric hardwoods)	38	41	15	38
Cave dwelling	6	7	0	0
Aquatic dependent	19	21	0	0

[a] Data summarized from species accounts presented in Wilson (1995).

Most salamander species find optimum habitat conditions in sawtimber stands.

Frogs and toads—The South is inhabited by numerous species of frogs and toads, each with its own particular requirements. The region supports such diversity due to its warm, humid climate, diversity of vegetative communities, and abundance of aquatic environments, particularly wetlands.

Wilson (1995) places these species into: (1) terrestrial species that migrate to standing water for egg deposition, (2) semiaquatic species requiring terrestrial habitat for dispersal, and (3) aquatic species that may use terrestrial habitat during rainy conditions. Each species requires standing water for egg deposition and larval development.

Several species exhibit two distinct stages: an aquatic larval stage (tadpole) and an adult stage. The eggs develop into tadpoles, which then undergo a complex metamorphosis into adults. The two stages have different habitat requirements that influence distributions and habitat associations.

Tadpoles consume algae and bacteria, while adult frogs and toads rely upon invertebrates. Some species, such as the pig frog, remain semiaquatic as adults, while others become terrestrial. Frogs and toads are important prey for wading birds, raptors, foxes, raccoons, and snakes.

Moisture also is a limiting factor for most frog and toad species; even terrestrial species require moist microhabitat (table 5.5). In addition to broad stream margins, frequently used habitats include both permanent and seasonal swamps and ponds. Many species, including the American toad and southern cricket frog, require moist soils for burrowing.

Leaf litter, potholes, and aquatic vegetation often provide moisture (table 5.5). The oak toad and pine barrens tree frog use leaf litter, while the southern chorus frog and the bird-voiced tree frog use aquatic vegetation. Potholes provide an important habitat component for Brimley's chorus and southern leopard frogs (Wilson 1995). Species that prefer open-canopy conditions include the Houston toad and the northern cricket frog.

Although wetlands are important breeding habitats, many frog and toad species spend part or all of their nonbreeding season in trees and shrubs. Forest structure creates diverse habitats with many niches. Forests also contribute organic matter and moderate the temperature and evaporation rate of adjacent aquatic habitats.

Southern frogs and toads inhabit a wide variety of forest cover types (table 5.6). Mesic, mixed pine and hardwood forests support 83 percent of species, including the American toad, Cope's gray tree frog, and northern cricket frog. Seventy-eight percent of the species inhabit bottomland hardwood forests, including Woodhouse's toads, pine woods tree frogs, squirrel tree frogs, and gray tree frogs. Longleaf pine, cypress-tupelo, and bay-pocosin habitats are used by over half of the frog species in the region. Oak and southern toads and southern cricket frogs occupy longleaf pine forests, while several tree frogs are characteristic of cypress-tupelo associations. It appears that a majority of species finds optimum and suitable habitat conditions in the grass, sapling, and poletimber stages (table 5.7).

Table 5.7—The relationship between forest successional stage and amphibian occurrence in the South[a]

Taxa subgroup/ habitat conditions	Grass/ forb	Seedling/ sapling	Pole- timber	Saw- timber
	Number of species			
Salamanders[b]				
Optimal[c]	0	0	0	76
Suitable[d]	10	15	25	5
Marginal[d]	6	50	54	0
Frogs and toads[e]				
Optimal	15	0	0	7
Suitable	16	34	31	14
Marginal	8	4	5	13

[a] Summarized from Wilson (1995).
[b] Based on habitat relationships information from 92 species.
[c] Habitats in which the species occurs with highest frequency.
[d] Habitats in which the species occurs with successively lower frequency.
[e] Based on habitat relationships information from 40 species.

Habitat management for amphibians—The complex life cycle of frogs and toads requires management of both terrestrial and aquatic habitats. Tiger salamanders and other ambystomas breed in the water but remain terrestrial during nonbreeding season. Thus, providing only one habitat component would fail to maintain viable populations of these species. Some terrestrial species require ponds or other standing water during the breeding season. Consequently, the removal of barriers such as roads between terrestrial habitat and aquatic habitat is important.

The semiaquatic species require aquatic areas that have rocks, woody debris, or other similar shelter in the water. Emergent and floating vegetation is important for breeding of some species. The adjacent terrestrial habitat also is important because many species, such as the *Eurycea* and *Desmognathus* genera, spend significant portions of their lives foraging and occupying terrestrial areas. Buffers adjacent to streams provide access to upland forested habitats. Aquatic habitats should be protected against thermal changes, water pollution, and excessive siltation (Wilson 1995). Habitat alteration due to dredging, channelization, and impoundment can be detrimental to many species.

Forest management alters the vegetative composition, seral stage, and structure of amphibian habitat. For example, prescribed burning temporarily removes leaf litter, herbaceous cover, and woody understory vegetation. Vegetative structure, snags, loose bark, and surface debris are important factors in managing amphibian habitat. Disking, windrowing, and furrowing during some forestry operations (Gibbons and Buhlmann 2001) may negatively impact species dependent upon the understory. Conversion from one forest type to another may be beneficial to some species and detrimental to others. The change in successional stage from sawtimber to grass-forb that results from timber harvest may enhance habitat suitability for one species, yet create marginal habitat for another.

Amphibian declines—Reported declines of amphibian populations have drawn considerable attention over the past two decades. Many are associated with high elevation, pristine areas that are remote from surrounding landscape modification. Amphibians are particularly sensitive to their environment. Their permeable skin and the lack of protective eggshells make them vulnerable to toxicants present in soil and water.

Southern species showing evidence of declines include the flatwoods salamander, Red Hills salamander, Texas blind salamander, wood frog, southern dusky salamander, and green salamander. Numerous others are categorized as imperiled and vulnerable (chapter 1). Endemic species are of particular concern in the Edwards Plateau, Ozark Highlands, Atlantic Coastal Plain, and Appalachian Mountains.

Amphibian declines have been attributed to several factors. These include habitat loss, wetland alteration, climate changes leading to droughts, diseases, exotic species, and agricultural chemicals. Other factors include acid precipitation and ultraviolet radiation. These are briefly reviewed later.

Wetlands and vernal pools are important for several amphibians. There have been significant losses of wetlands in the last two centuries (chapter 1). Declines in wetland quality through eutrophication, pollution, and fish stocking also impact amphibian populations. The hellbender is affected by stream degradation, while the gopher frog is influenced by the conversion of pine and hardwood forests to tree plantations, agriculture, and urban uses. In addition, habitat fragmentation by roads contributes to the mortality of breeding adults and dispersing juveniles (Wilson 1995).

Ozone depletion in the upper atmosphere increases the amount of ultraviolet radiation on the Earth's surface, particularly at high elevations. Ambient radiation damages cellular DNA (Reaser and Johnson 1997); amphibians with low levels of photolyase enzyme have embryos that are susceptible to ultraviolet radiation, which causes mortality and abnormal development, including skeletal, eye, and skin deformities.

Their porous skin makes amphibians susceptible to herbicides, pesticides, heavy metals, and petroleum products in aquatic systems. Pollutants such as gasoline, oil, and antifreeze sometimes occur in runoff into amphibian habitat. Relatively high nitrate levels cause physical and behavioral abnormalities in a number of species; synthetic chemicals interfere with hormonal processes, inhibiting amphibian development (Reaser 1996). The application of fertilizers and pesticides, particularly by aerial spraying, often impacts amphibians far from the point of application in nontarget areas.

The introduction of exotic species, such as fish, crayfish, and bullfrogs, into lakes and wetlands also influences amphibian populations. Fish introduced into wetlands for mosquito control prey upon amphibian eggs and larvae. Chytrid fungi, trematode parasites, and viruses carried by exotic fish may also contribute to population declines.

Several of the factors discussed above have been implicated as causes of amphibian abnormalities. These include parasite infestation, toxin contamination, radiation, radioactive salts, ground-level ozone, excessive heating of eggs, and reformulated gasoline (Reaser and Johnson 1997). Of these, only the parasite, toxin, radiation, and predation hypotheses have supportive evidence. The frequency of malformations is highest in frogs that have recently metamorphosed from tadpoles.

Concern about the status of amphibian populations is clearly warranted. Physiological constraints, limited mobility, and changes in site characteristics hinder recolonization of sites of local extinction. The temporal and spatial population dynamics of many amphibians are not well understood; it is unknown whether observed declines exceed natural population fluctuation.

There are other concerns facing individual amphibian species. Many of these are discussed in the section on reptiles, as these concerns are shared by herpetofauna as a group. In addition, some of these concerns are mentioned in Species accounts presented next.

Species accounts—The following are accounts for selected amphibian species that are of concern in the South. Several are federally listed as threatened or endangered. Others are classified as imperiled or vulnerable by Natural Heritage agencies. The species accounts and management recommendations follow Wilson (1995) unless otherwise noted.

Species accounts: flatwoods salamander—The population of this threatened species has declined during the past 10 to 15 years (Wilson 1995). The cause of the decline is uncertain, and the salamander is uncommon throughout its range from South Carolina, southern Georgia, and Florida westward to Mississippi.

The salamander inhabits pine flatwoods dominated by longleaf and slash pines and wiregrass, which is important for egg disposition. It is often found in association with cypress ponds, swamps, and pitcher plant bogs that are used for reproduction.

Management activities focus on avoidance of intensive site preparation before harvest, avoidance of prescribed burning during peak surface activity and breeding periods (November through April), and protection of breeding ponds. Fish stocking should be avoided (Bury and others 1980).

Species accounts: Florida bog frog—This species is classified as imperiled by Natural Heritage and is a species of special concern in Florida (NatureServe 2000). The frog is currently known to exist in 23 localities in the Panhandle (Moler 1992b). Many are found on the Eglin Air Force Base.

This frog species inhabits nonstagnant acidic seeps and the shallow backwaters of larger streams. It is frequently found in association with sphagnum moss and early seral stages of Atlantic white-cedar. Shrubby streamside habitats that do not have developing hardwood forests are preferred. The frog's diet consists of insects and other small arthropods.

Stream contamination and impoundment, and forest succession threaten the survival of this species (Moler 1992b). Conservation actions center on the protection of suitable habitat. Management of streamside vegetation to maintain the shrub-bog community is advised.

Species accounts: gopher frog—This uncommon species is classified as vulnerable by Natural Heritage (NatureServe 2000). Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina list the frog as of special concern. The gopher frog historically was distributed along the Gulf and Atlantic Coastal Plain, with isolated populations in the Valley and Ridge Province of Alabama. It was last documented from Louisiana in the 1960s. The frog has declined throughout its range with the loss of longleaf pine habitat (Martof and others 1980).

The gopher frog is associated with sandy pine flatwoods, turkey oak-pine sandhills, and xeric hammocks. It breeds in shallow, temporary ponds with open canopies and emergent herbaceous vegetation. Ditches and borrow pits are occasionally used. Adults seek refuge in the burrows of gopher tortoises, mice, and crayfish. Stump holes, root mounds, dense grass clumps, and thick mats of leaf litter may also be used.

The frog is an opportunistic feeder with a diet of arthropods, small frogs, and toads. Predators include water snakes, turtles, bluegills, and mosquitofish.

Management centers on protection of the sandhills and scrub-oak ecosystems and halting the losses of this habitat to circular irrigation farming and industrial development. Prescribed burning and other management practices that retain the open scrub nature of this habitat benefit this species (Wilson 1995), while practices that drain or alter breeding ponds are detrimental.

Species accounts: green salamander—This species is classified as vulnerable by Natural Heritage and is a species of special concern in Alabama, Georgia, Mississippi, and North Carolina (NatureServe 2000). Impoundment of several rivers in the Carolinas has extirpated several known populations.

The unique habitat of this species is limited and localized. The green salamander lives in damp crevices in shaded rock outcrops and under the bark of cove hardwood trees. It also is found in upland areas of Virginia pine and white pine-hemlock with mountain laurel understories. The salamander's diet consists of small insects, spiders, and earthworms.

Conservation efforts focus on protection of rock outcrops and the establishment of buffer zones in areas of timber harvest.

Species accounts: Houston toad—This endangered species is restricted to southeastern Texas, where its population is very small and fragmented. Human alteration of natural watersheds has eliminated many of its natural breeding pools, resulting in hybridization with the Gulf Coast toad and the Woodhouse's toad (Wilson 1995).

This toad inhabits areas with sandy, friable soils and is found most often in loblolly pine or mixed deciduous habitats interspersed with grassy areas under a range of conditions. Breeding habitats include roadside ditches, temporary ponds, and other seasonally flooded low spots. The toad's diet consists primarily of insects.

The recovery plan requires protection of critical habitat for this species. Habitat is maintained in a pristine state, and several breeding projects have been attempted. Development projects have been regulated in areas designated as critical habitat (Brown 1975).

Species accounts: one-toed amphiuma—This species is classified as vulnerable by Natural Heritage and listed as rare in Georgia (NatureServe 2000). It occurs in restricted geographic areas in northern Florida, Mobile Bay in Alabama, and the Ochlocknee River drainage in Georgia.

This semiaquatic salamander requires mucky habitats in association with permanent streams (Means 1992). Management actions center on protection of muck areas, which are threatened by sand and silt sedimentation during construction activities. Other actions include the regulation of amphiuma collection.

Species accounts: Red Hills salamander—This species is listed as threatened at both the Federal and State level. It is confined to a narrow belt within the Tallahatta and Hatchetigbee geological formations in the Red Hills of Alabama (Wilson 1995).

This nocturnal salamander lives in burrows on high, steep, uncut slopes with high soil moisture content and full tree canopy (Dodd 1991). The burrows are often near the base of a tree or under siltstone outcroppings. The salamander feeds on spiders and insects (U.S. Fish and Wildlife Service 1983, 1990b).

The majority of land in its range is privately owned. Habitat has been reduced by timber harvest, conversion of forest to agriculture, and ridgetop clearing. Overcollecting may have caused a decline in some areas. Feral hogs are a threat in localized areas (NatureServe 2001).

Conservation actions include cooperation with private and corporate landholders to restrict clearcutting and heavy site disturbance. Under public ownership, two areas have been set aside to support limited populations (NatureServe 2001). These include Alabama Forestry Commission and U.S. Army Corps of Engineers lands. In 1991, International Paper Company initiated work on a Habitat Conservation Plan (HCP) for this species. Other companies subsequently developed HCPs (Bailey 1995). Research needs include determination of the microhabitat effects of timber management practices and the collection of data on reproductive viability and recruitment within existing populations.

Species accounts: Shenandoah salamander—This species is endangered due to restricted range, habitat modification, and competitive interactions with the redback salamander. Inhabiting the high-elevation mountains of Virginia, the species requires talus slopes with deep soil pockets in mixed coniferous and deciduous forests. Its diet consists of small arthropods and earthworms.

Conservation efforts include restriction of construction activities that could disturb the limited talus habitats of this salamander (Martof and others 1980). Any construction of trails, roads, or overlooks in the Shenandoah National Park should be carefully monitored so as not to impact this salamander's limited habitat.

Species accounts: Tennessee cave salamander—This species is classified as imperiled by Natural Heritage and is listed as endangered in the States of Alabama and Tennessee (NatureServe 2000). The salamander is found in permanent streams and pools in limestone caves of central and southwest Tennessee, northern Alabama, and extreme northwest Georgia. It is believed to occur in approximately 1 percent of the caves in its range.

The Tennessee cave salamander feeds on arthropods, other small aquatic insects, and earthworms. Management centers on restricting human access and protecting limestone cave habitat. The species is very sensitive to pollutants and disturbances within its habitat (Wilson 1995).

Reptiles

The reptiles of the South belong to three orders: Crocodilia (alligators and crocodiles), Squamata (lizards, amphisbaenians, and snakes), and Testudinata (turtles). The South supports a diversity of reptiles (fig. 5.5), including 89 snakes (11 endemic), 75 lizards (6 endemic), 29 turtles (13 endemic), and 4 other reptiles (including 2 crocodilians). The number of reptile species ranges from 155 in Texas to 54 in Kentucky (NatureServe 2000). Species richness is impressive in Florida (94), Alabama (87), Georgia (87), and Mississippi (86).

The South's Coastal Plain possesses North America's highest diversity of reptiles (Gibbons and others 1997, White and others 1998). Twenty-nine percent of southern reptiles are classified as endemic (Dodd 1995a).

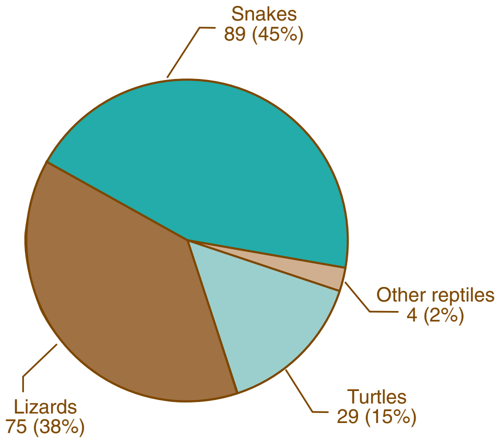

Figure 5.5—Species richness by major subgroups of reptilian taxa occurring within the South (NatureServe 2000).

Reptiles occupy forest, freshwater, marine, and urban habitats. Most use the same habitat for breeding and nonbreeding activities, but aquatic and marine species require adjacent terrestrial habitats in order to successfully reproduce.

The forested mountain regions also support an abundance of reptiles, including worm snakes, copperheads, ringneck snakes, bog turtles, and coal skinks. The longleaf pine-wiregrass community is vital habitat for the gopher tortoise and important habitat for mole skinks, glass lizards, scarlet snakes, pine snakes, and coachwhip snakes. Cypress-gum swamps are home to rainbow snakes, mud snakes, western green watersnakes, and striped crawfish snakes (Gibbons and Buhlmann 2001). Some reptiles play important roles in southern communities in nutrient cycling. Their burrows provide refuges for other species during extreme climatic conditions.

The numbers of turtles in Mississippi (31), Texas (30), Alabama (30), Georgia (27), Louisiana (26), and Florida (26) reflect the abundance of coastal and freshwater habitats. Numbers of lizard species in Texas (51) and Florida (38) far surpass the richness in other Southern States (NatureServe 2000). Both States are relatively large and have a wide variety of habitats in them. The number of lizards residing in the remaining States ranges from 17 species in Oklahoma to 8 species in Kentucky.

The number of snakes tends to be highest in the southernmost Coastal States. There are 73 in Texas, 46 in Florida, 42 in Alabama, 42 in Mississippi, 41 in Georgia, and 41 in South Carolina. Species richness in the mountain States is slightly lower. Virginia supports 30 snake species. Snakes reach their highest diversities in southern forests and their peripheral habitats, such as rivers, streams, and isolated wetlands.

Seventeen species of reptiles are listed as threatened or endangered by the U.S. Fish and Wildlife Service (table 5.8). In addition, numerous reptiles are classified as imperiled or vulnerable by the Natural Heritage agencies (chapter 1). Many of these species occur on the Coastal Plain; several are narrowly restricted endemics.

Although the variation in life-history traits is quite marked, many species of reptiles have long lives, variable reproductive rates, and high mortality among eggs and neonates. Such combinations of life-history characteristics are particularly common among turtles, crocodilians, and snakes.

Table 5.8—Reptile species within the South that are listed as threatened or endangered

Scientific name	Common name	Areas of occurrence
Turtles		
Caretta caretta	Loggerhead (T)	AL, FL, GA, LA, MS, NC, SC, TX, VA
Chelonia mydas	Green turtle (E)	AL, FL, GA, LA, MS, NC, SC, TX, VA
Clemmys muhlenbergii	Bog turtle (T)	GA, NC, SC, VA
Dermochelys coriacea	Leatherback; tinglar (E)	AL, FL, GA, LA, MS, NC, SC, TX, VA
Eretmochelys imbricata	Hawksbill (E)	AL, FL, GA, LA, MS, NC, SC, TX, VA
Gopherus polyphemus	Gopher tortoise (T)	AL, LA, MS
Graptemys flavimaculata	Yellow-blotched map turtle (T)	MS
Lepidochelys kempii	Kemp's or Atlantic ridley (E)	AL, FL, GA, LA, MS, NC, SC TX, VA
Pseudemys alabamensis	Alabama red-belly turtle (E)	AL
Sternothesis depressus	Flattened musk turtle (T)	AL
Lizards		
Eumeces egregius lividus	Bluetail mole skink (T)	FL
Snakes		
Drymarchon corais couperi	Eastern indigo snake (T)	AL, FL, GA, MS, SC
Nerodia clarkii taeniata	Atlantic salt marsh snake (T)	AL
Nerodia paucimaculata	Concho water snake (T)	TX
Other reptiles		
Alligator mississippiensis	American alligator (T)	AL, AR, FL, GA, LA, MS, NC, OK, SC, TX
Crocodylus acutus	American crocodile (E)	FL

T = Threatened; E = endangered.
Source: U.S. Department of the Interior (2000).

Due to their ectothermic physiology and seasonal inactivity, reptiles have relatively slow growth rates, advanced ages at maturity, and advanced generation times. Lizards have the youngest ages at maturity (1.5 years), while turtles and crocodilians have the oldest age at maturity (20 to 50 years). Age at maturity is estimated at over 30 years for some marine turtles.

Rates of reproduction are variable. Clutch frequency in sea turtles varies from one to four clutches every 3 to 4 years, whereas annual multiple clutches are common for some freshwater turtles. Reproduction occurs in alternate years (or less often) for terrestrial tortoises. Most lizards produce at least one clutch each year, and multiple clutches per year are common. In contrast, biennial reproduction is typical in snakes.

Turtles—Six turtle families are found in the South. These include the sea turtles, snapping turtles, water and box turtles, mud and musk turtles, tortoises, and softshell turtles. The greatest diversity occurs in the Coastal Plain, which supports a variety of freshwater and coastal marsh species and several species of sea turtles.

The gopher tortoise is a keystone species in the communities where it occurs. Its burrows provide refuges for a variety of species, including indigo snakes and diamondback rattlesnakes. The tortoise is threatened throughout its range as a result of habitat destruction associated with land development (Echternacht and Harris 1993).

Turtles are scavengers, herbivores, and carnivores and often contribute significant biomass to various ecosystems. They provide dispersal mechanisms for plants, contribute to environmental diversity, and foster symbiotic associations with a diverse array of organisms.

Many species have experienced significant declines in abundance and distribution during the last century. Among such species are the bog turtle, spotted turtle, common box turtle,

Table 5.9—The relationships of reptiles to physiographic features and other habitat elements[a]

Habitat element	Turtles		Lizards		Snakes		Alligators/ crocodiles	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Physiographic feature								
Sandhills	1	2	8	40	14	25		
Flatwoods	1	2	4	20	12	21		
Narrow stream margins	2	5	1	5	7	12		
Broad stream margins	11	27	1	5	18	32	1	50
Swamps	14	34	0	0	13	23	1	50
Cypress strands	2	5	0	0	8	14		
Cypress ponds	3	7	0	0	6	11		
Cypress drains	1	2	0	0	4	7		
Willow heads	1	2	0	0	3	5		
Bays and pocosins	3	7	1	5	9	16		
Rivers and streams	21	51	0	0	10	18	1	50
Permanent ponds	12	29	0	0	9	16	1	50
Vernal ponds	3	7	0	0	2	4		
Lakes	15	37	0	0	8	14	2	100
Marshes	13	32	0	0	16	28	1	50
Specific requirement								
Closed canopy	0	0	0	0	5	9		
Open canopy	29	71	14	70	43	75	2	100
Forest openings	3	7	10	50	8	14		
Shrub thickets	1	2	2	10	4	7		
Moist soil	5	12	3	15	11	19		
Sandy or friable soils	36	88	12	60	18	32		
Leaf litter	3	7	11	55	34	60		
Snags	0	0	4	70	3	5		
Fallen logs	0	0	11	55	35	61		
Rock outcrops	0	0	4	70	4	7		
Crevices and/or caves	0	0	1	5	5	9		
Seepages	4	10	0	0	1	2		
Potholes	1	2	0	0	3	5		
Aquatic rocks and/or logs	23	56	0	0	12	21	1	50
Aquatic vegetation	17	42	0	0	13	23	2	100

[a] Data summarized from species accounts presented in Wilson (1995).

gopher tortoise, common slider, and alligator snapping turtle. Some species, such as map turtles, have limited ranges, placing them at risk from habitat alteration or illegal collection for the pet trade. Disease also appears to contribute to population declines in some turtles. The diamondback terrapin was exploited heavily for food during the 19th century. Although the species recovered, the terrapin is again imperiled due to regional harvesting, habitat destruction, vehicular mortality, and drowning in crab traps (Lovich 1995).

Although the habitat requirements of marine turtles are beyond the scope of this terrestrial assessment, concerns over the future of these species warrants mention. Five species of marine turtles frequent the beaches, bays, estuaries, and lagoons of the South: loggerhead, green, Kemp's ridley, leatherback, and hawksbill turtles. These species have had dramatic declines attributable to commercial turtle fishing, exploitation of the juvenile populations, beach development, polluted water, incidental take, and diseases such as fibropapillomas. Monitoring is difficult due to their longevity. They continue to be threatened and their conservation involves international efforts.

Forest conditions influence both aquatic and terrestrial turtles. Map turtles, cooter turtles, and musk turtles inhabit streams and rivers that are influenced by adjacent riparian forests. Forest cover reduces sedimentation rates, affects water temperature, and influences availability of basking sites (Gibbons and Buhlmann 2001). In addition, many species such as mud turtles use terrestrial habitat for nesting and winter dormancy, spending the summer in wetland areas. Riparian forests are also quite important for map turtles.

Turtles inhabit areas with a variety of physiographic features (table 5.9). Not surprisingly, rivers, streams, swamps, lakes, and marshes figure prominently in their occurrence. Ninety percent of the species depend on aquatic environments. Common and alligator snapping turtles are found in swamps, deep rivers, and canals while marshes support bog and painted turtles. River and stream habitats support several species of map turtles.

Turtles are also associated with sandy soils, logs, and rocks that serve as shelter and as basking surfaces. The ornate box turtle and gopher tortoise require sandy or friable soils in which to burrow or deposit eggs (Wilson 1995). A majority of species (71 percent) prefers open-canopy conditions that aid in thermoregulation. Such species include the painted turtle, spotted turtle, Alabama map turtle, and striped mud turtle.

Tables 5.10 and 5.11 list the vegetative cover types and successional stages that are associated with turtles in the South. Bottomland hardwood forests support 81 percent of species, including the wood turtle, the common map turtle, and the Pascagoula map turtle. Sixty-three percent of the turtles occupy cypress-tupelo forests. These species include the Barbour's, the Escambia, and the yellow-blotched map turtle. Mesic, mixed pine-hardwoods stands are used by slightly over half of the southern species, including the painted and spotted turtles. Approximately one-third of the species find optimum or suitable habitat in grass-forb cover; most of these species presumably are associated with aquatic conditions.

Lizards and snakes—Four families of lizards inhabit the South. These species include anole, fence, collared, and horned lizards; whiptails; skinks; and glass lizards. All lizards are terrestrial; most species have small home ranges.

Sandhills and flatwoods are important habitats for lizards (table 5.9). The Florida scrub lizard, the island glass lizard, and the coal skink inhabit these areas. Leaf litter, fallen logs, and snags provide shelter as well as places to hunt for prey. The fence lizard and five-lined skink are associated with snags, while the slender glass lizard and the broad-head skink use fallen logs. Friable soils are an important habitat component for 60 percent of the species. Mimic and eastern glass lizards deposit eggs and burrow in these soils. The majority of species (70 percent) require an open forest canopy, a forest opening, or a rocky outcrop as basking sites for thermoregulation. Such species include the slender and island glass lizards, the collared lizard, and the Great Plains skink.

Twenty-one forest cover types are associated with lizards in the South (table 5.10). Although lizards in the region use a variety of forest cover, over half of the species inhabit longleaf pine-scrub oak, xeric mixed pine-hardwood, and live oak stands. Longleaf pine and scrub oak forests support the fence lizard, island glass lizard, and mimic glass lizard. The sand skink, ground skink, and six-lined racerunner occur in mixed pine and hardwoods. Live oak forests are used by 55 percent of the southern lizards, including the mole skink and broadhead skink. Mesic, mixed pine-hardwood stands also support a variety of lizards. Approximately half of the species find optimum conditions among grasses and forbs (table 5.11).

Three families of snakes occur in the South: nonvenomous snakes, coral snakes, and pit vipers. Species that inhabit the water are especially prevalent. Three of the largest snakes in North America occur in the region: the indigo snake, eastern diamondback rattlesnake, and timber rattlesnake.

In the absence of a large assemblage of mammalian predators, snakes assume special importance as top predators in some communities, and their low metabolic rates allow them to occur at impressive densities in undisturbed habitat (Echternacht and Harris 1993).

Since the larger species of snakes have fairly large home ranges—125 to 250 acres—fragmentation of existing habitat poses a significant threat (Wilson 1995). Several snakes, such as the brown snake and the common garter snake, have significant populations in suburban areas.

The majority of snake and lizard species have become imperiled due to insular populations, restricted ranges, habitat degradation, or the loss of suitable habitat. Malicious killing, biocides, exotic species, and illegal trade have also contributed to their decline.

Many snakes require shelter in the form of friable soil, fallen logs, leaf litter, rocks, or similar surface debris (table 5.9). As with lizards, snakes require open-canopy forest conditions to aid thermoregulation. Habitat management that leaves surface debris and tree stumps can benefit their habitat. Leaf litter and fallen logs provide refuges for snakes as well as their prey, which include invertebrates, small mammals, and amphibians. Racer and ringneck snakes are found in leaf

Table 5.10—The relationship between forest cover type and reptile occurrence in the South[a]

Forest cover types	Turtles		Lizards		Snakes		Alligators/ crocodiles	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Everglades	8	20	2	10	13	23	1	50
Tropical hardwoods	5	13	4	20	13	23	1	50
Mangroves	5	13	2	10	3	5	2	100
Longleaf-slash	2	5	4	20	11	19		
Pine-flatwoods	3	7	8	40	23	40		
Virginia-pitch pine (xeric upland pines)	1	2	5	25	14	25		
Longleaf pine	4	10	15	19	21	37		
Loblolly-shortleaf pine	5	12	7	35	20	35		
White pine-hemlock	4	10	2	10	16	28		
Pond pine	2	5	2	10	4	7		
Longleaf-scrub oak	2	5	10	50	13	23		
Mixed, pine-hardwood (mesic)	22	54	8	40	37	65		
Mixed, pine-Hardwood (xeric)	3	7	11	55	15	26		
Spruce fir	0	0	0	0	1	2		
Upland hardwoods (mesic) - white oak-red oak	9	22	3	15	25	44		
Cypress tupelo	26	63	3	15	12	21	1	50
Bottomland hardwoods- (sweetgum-willow oak)	33	81	5	25	29	51	1	50
Sweetgum-yellow-poplar	16	39	1	5	9	16		
Bay-pocosin	9	22	3	15	10	18		
Live Oak (maritime)	1	2	11	55	22	39		
Maple-beech	4	10	1	5	16	28		
Cove hardwoods	0	0	0	0	3	5		
Spartina	7	17	0	0	3	5	2	100
Elm-ash	0	0	0	0	5	9		
Oak-hickory (xeric hardwoods)	4	10	3	15	24	42		
Aquatic dependent	37	90	0	0	15	26		

[a] Data summarized from species accounts presented in Wilson (1995).

litter, while fallen logs are important habitat components for indigo and corn snakes. Seventy-five percent of snake species are associated with open canopy forest; these include scarlet and Kirtland's snakes.

Forests provide essential habitat components for terrestrial species as well as those that live in aquatic habitats. Table 5.10 presents the 26 vegetative cover types that are associated with snakes in the South. Snakes use a diversity of forest cover; there are, however, a group of specific types that are used most often. Mesic, mixed pine and hardwood forests support 65 percent of species, including the western worm snake, corn snake, and rat snake. Fifty-one percent of the snakes occupy bottomland hardwoods. These species include the mud, rainbow, and scarlet king snake. Mesic upland hardwoods and xeric oak-hickory hardwoods are used by over 40 percent of the southern species. The prairie king snake, milk snake, and the common water snake occupy mesic hardwood types, while eastern and southern hognose snakes are characteristic of xeric hardwoods. The pine flatwoods forests also support a variety of snakes.

Table 5.11 illustrates the relationships between snake occurrence and forest successional stage. Approximately half of the species find suitable habitat in seedling-sapling and poletimber conditions. Slightly more species find optimum and suitable conditions in grass-forb stages than in sawtimber stands.

Crocodilians—Two native species of crocodilians, the America alligator (family Alligatoridae) and the American crocodile (family Crocodylidae), occur in the South. A large breeding population of the introduced spectacled caiman, native to the American tropics from southern Mexico to Argentina, occurs in Dade County, FL (Echternacht

Table 5.11—The relationship between forest successional stage and reptile occurrence in the South[a]

Taxa subgroup/ habitat condition	Successional stage: Grass	Sapling	Pole-timber	Saw-timber
Turtles[b]				
Optimal[c]	13	0	0	0
Suitable[d]	3	8	8	4
Marginal[d]	0	7	5	8
Lizards[e]				
Optimal	10	1	0	1
Suitable	3	13	14	11
Marginal	3	6	2	1
Snakes[f]				
Optimal	7	1	0	6
Suitable	33	46	43	29
Marginal	11	8	6	8
Alligators and crocodiles[g]				
Optimal	2	0	0	0
Suitable	0	0	0	0
Marginal	0	2	1	0

[a] Summarized from Wilson (1995).
[b] Based on habitat relationships information from 41 species.
[c] Habitats in which the species occurs with highest frequency.
[d] Habitats in which the species occurs with successively lower frequency.
[e] Based on habitat relationships information from 20 species.
[f] Based on habitat relationships information from 57 species.
[g] Based on habitat relationships information from 2 species.

and Harris 1993). This exotic species is discussed further in chapter 3.

The alligator is a wide-ranging animal that occurs from coastal North Carolina south to Florida and westward to eastern Texas. It has recovered from previous declines and now has pest status in Louisiana and Florida. The alligator creates marsh pools that provide habitat for many other species. Its larger and more secretive relative, the American crocodile, is restricted in its North American range to extreme south Florida.

During the last century, wetland drainage for agriculture and development activities permanently reduced alligator populations in freshwater marshes. Recent environmental contamination has been associated with declines in alligator populations (Woodward 1995). Widespread pollution of wetlands by toxic petrochemicals and metals may continue to threaten population viability. Although the status of the Florida alligator population appears secure, continued habitat loss and toxic contamination may compromise its conservation.

The crocodile remains endangered, while the alligator is federally listed as threatened due to "similarity of appearance." This designation reflects the special instance when a species so closely resembles a listed species that it is difficult in the wild to differentiate between the two. The effect of this difficulty is an additional threat to the listed species.

The alligator is doing well in suitable habitat, while the crocodile is struggling to survive in its limited range in southern Florida (Wilson 1995). Management plans for both species protect aquatic and terrestrial habitat, particularly for nesting and basking. Management includes captive programs to manage the species for meat and hide production, as well as effective protection from poaching.

Not surprisingly, both species occur in areas limited in the number of physiographic features and vegetative cover types (tables 5.9, 5.10, and 5.11). Lakes, marshes, rivers, streams, permanent ponds, and swamps figure prominently in their occurrence. Aquatic vegetation is important to both species; rocks and logs in the water serve as useful basking areas. Alligators and crocodiles require open canopy forest conditions to aid thermoregulation. This need may explain their use of stands of grasses and forbs.

Six vegetative cover types are associated with these species in the South. Mangrove and spartina habitat supports both species. Tropical hardwoods, cypress tupelo, and bottomland hardwood forests are also occasionally used. Additional details on each species are presented in the Species accounts at the end of the reptile section.

Habitat management for reptiles— The general problems faced by reptiles in southern forests center on the environmental impacts resulting from human activities. Difficulties in assessing problems and monitoring populations hinder management of these vertebrates.

The life history and ecology of reptiles differ markedly from those of other taxa. Many reptile species take longer to mature and have long lifespans. For example, the forest-inhabiting box turtle and snapping turtle take over 10 years to reach sexual maturity (Gibbons and Buhlmann 2001). Managing for sustainable populations of long-lived, late-maturing species requires different strategies than for short-lived, rapid turnover species (Congdon and others 1994, Ernst and others 1994).

The primary threats to reptiles in the South stem from habitat destruction and alteration, including changes in water quality. The drainage of wetlands and temporary ponds has reduced the population of striped newts (Dodd 1995a) and extirpated the flatwoods salamander from a portion of its range (White and others 1998). Destruction of wetlands has reduced spotted turtle populations, and other aquatic habitats do not meet the turtle's specialized needs.

Impoundments have affected several species of map turtles native to large southern rivers. The damming of streams to form reservoirs has contributed strongly to the eliminating several species (Mitchell 1994). In addition, the removal of dead trees and the dredging of river bottoms, which harbor mollusks that the turtles eat, have negatively affected these species.

The gopher tortoise and other reptiles have become threatened in part because of the loss of longleaf pine habitat (Dodd 1995b, Guyer and Bailey 1993). Many species of snakes and box turtles are also declining in numbers due to loss of suitable habitat. Accidental death by vehicles and intentional killing are other factors contributing to snake decline. Several of these reptiles, such as short-tailed snakes and flattened musk turtles, have relatively small geographic ranges. Others, such as the pinewoods snake, coal skink, and Webster's salamander, have disjunct populations that make them quite vulnerable to habitat loss. Effects of habitat alteration can be far-reaching.

Management of sea turtles has emphasized the acquisition and protection of nesting habitat. Other concerns include ocean pollution, fishing and shrimping nets, beach development, and enforcement of international regulations. The identification of migration routes and other life history information also will benefit future management strategies.

Degradation of aquatic habitat is the primary management concern for freshwater turtles. Conservation actions are directed at monitoring the extent of thermal pollution, dredging, channelization, and incidental takes by commercial fishing. Protection of nesting beaches and adjacent nest areas, and the prevention of deliberate killing are also important management priorities.

In addition to intentional killing, which affects snakes as well as turtles, several reptiles suffer direct losses due to exploitation. Unregulated harvest affects a number of the listed turtle and tortoise populations, as well as the majority of sea turtles. Collection for the pet trade is another serious management problem. Some species, particularly the genera *Clemmys* and *Graptemys*, require strict regulation due to rising demands in domestic and foreign pet markets. Commercial collectors also threaten the spotted turtle and box turtle.

The invasion of introduced exotics can also be detrimental to native reptiles. Fire ants, in particular, have been implicated in the reduction of terrestrial egg-laying reptiles (Mount 1986).

Management can enhance reptile habitat in many ways. One way is through the retention of microhabitat features that provide refuges. For example, the disruption of underground root systems in managed pine plantations may displace species such as the eastern diamondback rattlesnake. The importance of leaving terrestrial buffer zones around forest wetlands is well documented (Burke and Gibbons 1995, Semlitsch and Bodie 1998). The retention of habitat elements such as leaf litter, snags, coarse woody debris, and fallen logs benefits the habitat of many reptiles (refer to the individual subtaxa sections mentioned earlier and Species accounts that follow).

Delayed sexual maturity and individual longevity contribute to the vulnerability of reptiles and inhibit the recovery of several threatened species. Several reptiles have existed virtually unchanged for centuries. Unfortunately, some of the same traits that allowed them to survive the ages predispose them to endangerment. Conservation actions should be directed towards areas of high species diversity, species with limited distributions, and locations such as shallow wetlands and coastal zones where reptiles are at risk. Insufficient knowledge of the distribution and ecology of native reptiles is a major shortcoming in any regional effort to detect change and avoid loss in these taxa.

Species accounts—The following are the species accounts for selected reptiles that are of concern in the South. Several are federally listed as threatened or endangered. Others are classified as imperiled or vulnerable by Natural Heritage agencies. Management recommendations follow Wilson (1995) unless otherwise cited.

Species accounts: Alabama redbelly turtle—This endangered species is restricted to Mobile Bay in southern Alabama. It has declined due to habitat modification and because it was trapped and netted for food (Dobie and Bagley 1988). Habitat disturbance has altered the turtles' nesting and feeding habitat.

Primary habitat areas are the upper, freshwater portions of Mobile Bay, where there are abundant supplies of submerged plants and algae, which are preferred foods.

Conservation actions emphasize protection of the primary nesting site on Gravine Island, restriction of herbicide use, and limitation of dredging activity on the lower Tensaw River.

Species accounts: alligator snapping turtle—This species is classified as vulnerable by Natural Heritage and is listed in the States of Alabama, Georgia, and Texas (NatureServe 2000). The turtle has declined due to habitat loss and commercial exploitation for food and the pet trade.

The species is typically found in deep rivers and canals, but may also occur in lakes, swamps, and small streams. Although it nests on land, the turtle is primarily aquatic and feeds on fish, mollusks, and crayfish.

Conservation measures include regulation of collection and the protection of suitable habitat with adequate prey populations (Wilson 1995).

Species accounts: American alligator—This species is federally listed as threatened due to similarity of appearance to the American crocodile. The alligator ranges from coastal North Carolina to extreme southern Florida, west to east Texas, and north to central Arkansas. Current threats include the conversion of habitat for recreational use and urban development.

Alligators prefer large, shallow lakes, fresh or brackish marshes, and savannas that border aquatic habitat. Alligators are strictly carnivorous and will eat any animal they can subdue and swallow.

Conservation actions for the American alligator focus on habitat protection and control of human disturbance.

Species accounts: American crocodile—The crocodile is federally listed as endangered. The species occurs in south Florida and the Florida Keys. It inhabits the Caribbean, Central America, and South America. Habitat loss is the primary reason for this species' imperilment in the South (Moler 1992a).

The crocodile is found in brackish or salt water in coastal canals, mangrove thickets, or tidal creeks. The crocodile is carnivorous. Conservation actions center on protection of the remaining habitat in southern Florida (Wilson 1995).

Species accounts: Atlantic salt marsh snake—This threatened species is restricted to a small coastal strip in Florida. It is imperiled by wetland habitat alteration stemming from drainage and impoundment.

This snake preys on fish and is typically found in salt marshes, tidal creeks, and mangrove swamps. Conservation action for this species is concerned with protection of the remaining unaltered habitat (Conant and Collins 1991).

Species accounts: bog turtle—This threatened species occurs in southwestern Virginia, eastern Tennessee, northern Georgia, and the Carolinas. The bog turtle is in jeopardy due to collection for the pet trade and habitat loss. The drainage of grassy and marshy wetlands has resulted in the destruction of the required habitat for this species.

The bog turtle feeds on a variety of animals including tadpoles, frogs, various invertebrates, and baby rodents. The species does not tolerate closed-canopy forests. Management actions focus on the maintenance of early seral (grassy) habitat and halting the illegal pet trade (Ernst and others 1994). Drainage of wetlands is detrimental to this species (Wilson 1995).

Species accounts: Florida scrub lizard—This species is classified as vulnerable by Natural Heritage (NatureServe 2000). Disjunct populations occur along the east coast of Florida, in central Florida, and in isolated areas on the west coast of Florida. The species is threatened by conversion of habitat to other uses.

The lizard prefers open sandy edges in xeric sand pine scrub and longleaf pine habitat (Conant and Collins 1991). It feeds on ants, beetles, spiders, and other small arthropods.

Conservation strategies focus on the management of sand pine scrub and longleaf pine-turkey oak habitats to retain the open character that the lizard requires. The Ocala National Forest manages large areas of this habitat (Wilson 1995). Habitat maintenance often requires prescribed burning.

Species accounts: gopher tortoise—This threatened species occurs in Florida, Georgia, South Carolina, Mississippi, Alabama, and Louisiana. Habitat loss and the pet trade are the primary factors contributing to the decline of the tortoise (U.S. Fish and Wildlife Service 1990c).

Well-drained sandy soils supporting pine and scrub oaks in the sandhills are preferred habitat. The tortoise feeds on grasses, forbs, and other vegetation (Ernst and others 1994).

Habitat management for the gopher tortoise includes selective harvest and prescribed burning to maintain the open, grassy nature of sand ridges. Ground disturbance such as heavy site preparation and root raking can be detrimental to young tortoises (Wilson 1995).

Species accounts: indigo snake—The population of this threatened species has declined rapidly in recent years. Primary threats appear to be habitat loss and exploitation for the pet trade (Speake and others 1982). The indigo snake is currently found in southeastern Georgia and Florida.

The species coexists with gopher tortoises throughout much of its range and frequently uses tortoise burrows. Preferred habitat is pine-scrub oak woodlands and palmetto-covered hills with well-drained sandy soils. Indigo snakes may also be found in mesic habitats bordering swamps, streams, or canals. The snake feeds on frogs, toads, birds, small mammals, and other reptiles.

Conservation actions necessary to protect indigo snake populations include the retention of existing habitat, maintenance of pine-scrub oak woodlands in a subclimax condition, and protection of gopher tortoise burrows (Moler 1992c).

Species accounts: Louisiana pine snake—This species is endemic to eastern Texas and western Louisiana, primarily in areas currently or once dominated by longleaf pine. The species is associated with fire-maintained pine forests on well-drained sandy soils with well-developed herbaceous vegetation (Rudolph and Burgdorf 1997). Pocket gophers are the primary prey of Louisiana pine snakes, and pocket gopher burrows are used for escape from predators, avoidance of high temperatures, and hibernation. The species has apparently declined in recent decades, and existing populations are thought to be small and isolated (Reichling 1995, Rudolph and Burgdorf 1997).

Loss of habitat due to conversion to intensive silviculture and changes in the fire regime are the primary causes of population decline. Fire suppression and inadequate prescribed fire have resulted in widespread successional changes in pine forests throughout the range of Louisiana pine snakes, leading to loss of herbaceous vegetation and pocket gophers. Habitat loss and degradation has been more extensive on private than on public land. Roads and associated vehicle traffic are very likely impacting populations in much of the remaining habitat.

Conservation action centers on the management of fire-maintained pine habitat on a scale sufficient to support viable populations of this species. Prescribed burning sufficient to maintain abundant herbaceous vegetation and support of pocket gopher populations are required.

Species accounts: mimic glass lizard—This species is classified as vulnerable by Natural Heritage (NatureServe 2000). The lizard occurs on the Atlantic Coastal Plain from North Carolina to Florida and westward as far as the Pearl River in Mississippi. The species is imperiled due to excessive development and habitat modification in its range.

The lizard inhabits open-canopied pine forests with thick forest litter. It feeds on a variety of invertebrate prey as well as small lizards and snakes (Palmer and Braswell 1995).

Conservation actions to benefit this species include maintaining an open canopy through burning and thinning (Wilson 1995).

Species accounts: bluetail mole skink—This threatened subspecies occurs in Florida. Residential development and agricultural conversion have altered its habitat. The mole skink prefers open, sandy edges in sand pine scrub and sandhill habitats. The species consumes a variety of invertebrate prey, including ants, beetles, and spiders.

Conservation actions for this species focus on protection of essential habitat areas from conversion to other uses (Conant and Collins 1991).

Species accounts: rim rock crowned snake—This species is classified as critically imperiled by Natural Heritage and occurs solely in Florida (NatureServe 2000). Development and the resultant habitat loss threaten the snake.

This snake is found in flatwoods, tropical hardwood hammocks, and pastures and on fossil coral reefs (Porras and Wilson 1979). This snake consumes insects and other small arthropods.

Because of the intense development occurring in the habitat of this species, conservation action centers on the protection of suitable habitat (Wilson 1995).

Species accounts: ringed map turtle—This threatened turtle inhabits the Pearl River drainage of southern Mississippi and southeastern Louisiana. Primary threats are illegal collection for the pet trade and habitat degradation (U.S. Fish and Wildlife Service 1988).

This turtle leaves the river to bask and to lay eggs. Preferred habitat includes river stretches with moderate current, sandbars, and debris for basking sites. The diet is comprised of insects and mollusks. Because this turtle is restricted to the Pearl River, modifications of natural conditions there could prove detrimental.

Species accounts: sand skink—This species is classified as imperiled by Natural Heritage (NatureServe 2000). It is restricted to well-drained sandy soils in the interior central Florida highlands. Much of this habitat has been converted to citrus groves and residential areas.

The sand skink lives in loose, dry sandy areas with sparse grass cover. It subsists on a diet of ants, spiders, termites, beetle larvae, and other invertebrates.

Protection of the remaining habitat and acquisition of additional areas are the primary conservation actions required to preserve this species (Christman 1992). In addition, the use of prescribed fire is important for maintaining the open nature of sand skink habitat.

Species accounts: short-tailed snake—This species is classified as vulnerable by Natural Heritage and is endemic to Florida (NatureServe 2000). Habitat destruction is the primary threat, particularly in central Florida, where land is in demand for agricultural, residential, and other uses (Wilson 1995).

The primary habitats of this snake are longleaf pine-turkey oak and sand pine scrub communities with loose sandy soils. It feeds on small snakes and lizards.

Management actions center on the protection of remaining occupied habitat from development and the retention of prey populations (Campbell and Moler 1992).

Species accounts: southern hognose snake—This species is classified as imperiled by Natural Heritage (NatureServe 2000). The snake occurs primarily on the Coastal Plain from North Carolina westward into southern Mississippi. There is one disjunct population in central Alabama. Development of preferred habitat is the primary cause for imperilment, but fire ants may also be impacting populations (Wilson 1995).

This snake is found in sandhills, pine-scrub oak woodlands, pine and wiregrass flatwoods, and other open xeric communities with loose, sandy soils (Martof and others 1980). It feeds primarily on toads, frogs, and lizards.

Conservation actions for this species include the protection and restoration of remaining habitat, restriction of additional development, and fire ant control.

Mammals

Terrestrial, marine, and freshwater habitats in the South are home to 246 mammalian species (NatureServe 2000). The number of mammals ranges from 176 species in Texas to 62 species in Mississippi. There are 102 species in Georgia, 101 in South Carolina, 96 in Oklahoma, and 95 in Florida. The total includes rodents, carnivores, bats, whales, dolphins, and other mammals (fig. 5.6).

This vertebrate group comprises 11 major orders and 26 families (Echternacht and Harris 1993). All but five families have one or more sensitive species (Laerm and others 2000). These families include Didelphidae (opossum), Dasypodidae (armadillo), Castoridae (beaver), Myocastoridae (nutria), and Suidae (wild boar). The order Rodentia dominates the region's mammalian fauna in the number of different species. This order includes chipmunks, squirrels, pocket gophers, mice, rats, voles, muskrats, nutria, and beavers. Examples of carnivores include the Florida panther, red fox, bobcat, river otter, and mink. The category of "other mammals" in figure 5.6 includes the Florida manatee, white-tailed deer, eastern cottontail rabbit, opossum, armadillo, shrews, moles, and several other species.

Five mammal species are known or presumed to be extinct or extirpated from the region. These are the jaguar, ocelot, gray wolf, elk, and bison (Echternacht and Harris 1993). Beavers were once extirpated in the South but were reestablished over the past two decades.

Endemic species represent a relatively small percentage of the mammals in the region. Eight rodent species are endemic to the Coastal Plain: the southeastern pocket gopher, colonial pocket gopher, Sherman's pocket gopher, Cumberland Island pocket gopher, oldfield mouse, Florida mouse, Perdido Key beach mouse, and round-tailed muskrat (White and others 1998). The region also has eight species of introduced mammals, including the coyote, wild boar, and nutria.

Thirty-three species of mammals are listed as threatened or endangered (table 5.12). These include the Key deer, red wolf, Louisiana black bear, Indiana bat, gray myotis, Virginia northern flying squirrel, and southeastern beach mouse. Ten of the listed rodent species inhabit the Coastal Plain of Florida or Alabama.

In addition, 12 species are classified as imperiled or vulnerable under the Natural Heritage system (chapter 1).

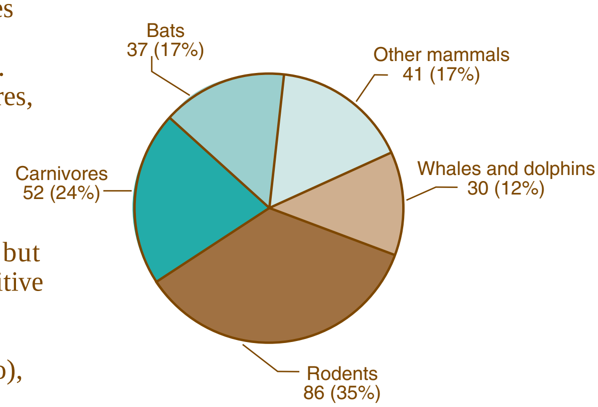

Figure 5.6—Species richness by major subgroups of mammalian taxa occurring within the South (NatureServe 2000).

Table 5.12—Mammal species within the South that are listed as threatened or endangered

Scientific name	Common name	Areas of occurrence
Bats		
Corynorhirus townsendii ingens	Ozark big-eared bat (E)	AR, OK
Corynorhinus townsendii virginianus	Virginia big-eared bat (E)	NC, VA
Myotis grisescens	Gray bat (E)	AL, AR, FL, GA, KY, OK, TN, VA
Myotis sodalis	Indiana bat (E)	AL, AR, GA, KY, MS, NC, OK, SC, TN, VA
Rodents		
Glaucomys sabrinus coloratus	Carolina northern flying squirrel (E)	NC, TN
Glaucomys sabrinus fuscus	Virginia northern flying squirrel (E)	KY, NC, VA
Microtus pennsylvanicus dukecampbelli	Florida salt marsh vole (E)	FL
Neotoma floridana smalli	Key Largo woodrat (E)	FL
Oryzomys palustris natator	Rice rat (E)	FL
Peromyscus gossypinus allapaticola	Key Largo cotton mouse (E)	FL
Peromyscus polionotus allophrys	Chocawhatcher beach mouse (E)	FL
Peromyscus polionotus ammobates	Alabama beach mouse (E)	AL
Peromyscus polionotus niveiventris	Southeastern beach mouse (T)	FL
Peromyscus polionotus peninsularis	St. Andrew beach mouse (E)	FL
Peromyscus polionotus phasma	Anastasia Island beach mouse (E)	FL
Peromyscus polionotus trissyllepsis	Perdido key beach mouse (E)	AL, FL
Sciurus niger cinereus	Delmarva Peninsula fox squirrel (E)	VA
Carnivores		
Canus rufus	Red wolf (E)	NC, TN, FL
Herpailurus yogouaroundi cacomitli	Gulf Coast jaguarundi (E)	TX
Leopardus pardalis	Ocelet (E)	TX
Panthera onca	Jaguar; Otorongo (E)	TX
Puma concolor	Puma (T)	FL
Puma concolor coryi	Florida panther (E)	FL
Puma concolor cougar	Eastern puma (E)	KY, NC, SC, TN, VA
Ursus americanus luteolus	Louisiana black bear (T)	LA, MS, TX
Whales and dolphins		
Balaenoptera physalus	Fin whale (E)	AL, FL, GA, LA, MS, NC, SC, TX, VA
Eubalaena glacialis	Black right whale (E)	FL, GA, NC, SC, VA
Megaptera novaeangliae	Humpback whale (E)	AL, FL, GA, LA, MS, NC, SC, TX, VA
Physeter catodon	Sperm whale (E)	NC
Other mammals		
Monachus tropicalis	Caribbean monk seal (E)	FL
Odocoileus virginianus clavium	Key deer (E)	FL
Trichecchus manatus	Manatee (E)	AL, FL, GA, LA, MS, NC, SC, TX
Sylviagus palustris hefneri	Lower Keys marsh rabbit (E)	FL

T = threatened; E = endangered.
Source: U.S. Department of the Interior (2000).

These include the Rafinesque's big-eared bat, gray-footed chipmunk, round-tailed muskrat, Allegheny woodrat, and swift fox. These species are in jeopardy due to habitat loss, land use change, human disturbance, and coastal development.

The white-tailed deer is the most widespread browsing species represented in the region today. Elk have recently been reintroduced into selected locations. The absence of large carnivores (wolves, jaguar) reflects history since European settlement (chapter 1). The black bear is the largest carnivore now in the South. Four wild canids occur in the region. The coyote has expanded its range, while the red wolf is critically imperiled due to habitat loss and hybridization with other canids. Red and gray foxes remain relatively common. The Florida panther is in jeopardy, while the bobcat remains widespread throughout the region.

The absence of large predators has encouraged the proliferation of raccoons, opossums, and skunks. These species demonstrate broad ecological tolerance, inhabiting virtually every type of habitat available. They consume a variety of foods: frogs, turtles, snakes, mice, berries, and other vegetation. These mammals are rapidly becoming urban wildlife in many communities of the South.

Rodents are a diverse group that persists in abundance in many areas. They tend to have high birth rates that permit the maintenance of stable populations despite predation pressure and control measures. The rodent species that are most at risk in the South have narrow distributions. In beach habitats, feral cats represent a significant threat. Pesticide residues affect shrews and other insectivores. The fox squirrel that inhabits longleaf pine savannas is threatened by fire suppression and land use conversion (White and others 1998).

The absence of mountain barriers and other opportunities for isolation and speciation contribute to the lack of species richness among squirrels and burrowing mammals (Echternacht and Harris 1993). The eight species of sciurid rodents in the region include the 13-lined ground squirrel, gray squirrel, fox squirrel, and two flying squirrels. The region's 10 burrowing rodents include the hairy-tailed mole, eastern mole, and star-nosed mole; woodchuck; eastern chipmunk; and 5 species of pocket gophers. Soil type is the primary factor determining the ranges of pocket gophers.

The following sections discuss the habitat needs for two of the highest profile groups of mammals: bats and carnivores. Additional species are also profiled in the Species account section that concludes the segment on mammals.

Bats—The 20 species of bats in the South are key components of forested ecosystems. Four bats are listed as endangered: the gray bat, Indiana bat, and Ozark and Virginia big-eared bats (table 5.13). The southeastern bat, the eastern small-footed bat, Rafinesque's big-eared bat, and Wagner's mastiff bat are of special concern.

Forest bats depend on forests for shelter, roosting sites, and foraging areas. Bats are in two major classes: cave bats and tree bats. Cave bats inhabit caves during all or part of the year, while noncave species seldom enter caves. Some of their ranges are limited to relatively small geographic areas. Insectivorous bats have tiny

Table 5.13—Bat species occurring within the South

Scientific name	Common name	Status
Artibeus jamaicensis	Jamaican fruit-eating bat	Limited numbers
Corynorhinus townsendii	Townsend's big-eared bat	Endangered[a]
Corynorhinus rafinesquii	Rafinesque's big-eared bat	Special concern
Eptesicus fuscus	Big brown bat	Common
Eumops glaucinus	Wagner's mastiff bat	Rare
Lasionycteris noctivagans	Silver-haired bat	Relatively uncommon
Lasiurus borealis	Eastern red bat	Common
Lasiurus cinereus	Hoary bat	Relatively common
Lasiurus intermedius	Northern yellow bat	Relatively common
Lasiurus seminolus	Seminole bat	Common
Molossus molossus	Pallas mastiff bat	Limited numbers
Myotis austroriparius	Southeastern bat	Special concern
Myotis grisescens	Gray bat	Endangered
Myotis leibii	Eastern small-footed bat	Special concern
Myotis lucifugus	Little brown bat	Scarce or locally common
Myotis septentrionalis	Northern long-eared bat	Common
Myotis sodalis	Indiana bat	Endangered
Nycticeius humeralis	Evening bat	Common
Pipistrelle subflavus	Eastern pipistrelle	Common
Tadarida brasiliensis	Brazilian free-tailed bat	Locally common/abundant[b]

[a] Two subspecies: Ozark big-eared bat and the Virginia big-eared bat.
[b] Two subspecies: LeConte's free-tailed bat and the Mexican free-tailed bat.
Source: Adapted from Harvey and Saugey (2001).

eyes and are capable of sight, but most species locate prey by echolocation.

Bats hibernate in a variety of locations including leaf litter, woody debris, caves, hollow trees, and rock crevices. Many species hibernate under exfoliating bark and in tree cavities, mines, and buildings. Roosting sites range from solitary sites to caves containing thousands of individuals. Sites selected for roosting and hibernation meet precise environmental conditions, such as stable temperatures and high relative humidity. Disturbance often results in the abandonment of the site.

Bats have evolved to fill a variety of food niches. These mammals begin foraging at dusk. The diet consists of insects and other arthropods and varies by species.

Widespread pesticide use caused significant declines in bat populations during the past several decades (Harvey and others 1999). This threat has diminished somewhat with pesticide use regulations. The current threat to bats stems from habitat destruction and cave disturbance. Few caves meet the narrow temperature and humidity requirements for hibernation. The large numbers of bats occupying specific caves make these species vulnerable to disturbance of an individual cave.

Various locations are used as maternity roost sites. Snags are used by Indiana, northern, and evening bats, while hollow trees are important for Rafinesque's and southeastern bats. A particular threat is human disturbance to hibernation and maternity colonies. Hibernating bats wake when disturbed and expend critical winter stores of fat. Summer maternity colonies have low tolerance of disturbance; disturbed parents will often abandon their offspring. Bats produce an average of one offspring per year, but some species give birth to three or four babies at a time. The low rate of reproduction results in populations that can be quickly destroyed with little opportunity for recovery. Other adverse impacts include habitat destruction; direct killing; vandalism; and predation by raptors, raccoons, skunks, and snakes (Tuttle 1995).

A number of forest management actions can enhance bat habitat. Seed-tree and shelterwood harvests open up forest canopies, creating foraging opportunities by reducing branch obstructions (Krusic and others 1996). Retention of cavity trees and snags, creation of large snags, and designation of streamside zones also are beneficial (Harvey and Saugey 2001, Kulhavy and Conner 1986). The creation of ponds can also enhance habitat by providing water, breeding sites, and a source of insect prey (Wilhide and others 1998).

Even-aged poletimber stands often are unsuitable for bole and cavity users and do not provide the cavities and bark characteristics preferred by bats (Pierson 1998). Clearcutting eliminates roosting opportunities until replacement trees of suitable size become available (Harvey and Saugey 2001). However, the resulting availability of herbaceous growth results in increased insect populations (Barclay and Brigham 1998). Stand rotations long enough to allow for cavity development are important for species that require cavities.

Prescribed burning can enhance invertebrate biomass by reducing midstory trees and shrubs, allowing the regeneration of herbaceous plants. The resulting canopy gaps provide additional foraging opportunities. However, fire may jeopardize bats hibernating on the ground during winter when they are torpid and slow to arouse (Harvey and Saugey 2001). The impact of dormant-season burning on species that roost in ground litter is unclear. Snags used by bats may be felled by fire if their bases burn through, resulting in the loss of cavities or roosting sites under exfoliating bark.

Finally, recreational caving should be minimized to prevent disturbance to maternity and hibernating colonies. Properly designed gates on cave entrances afford the best protection. Other protective measures include limiting the use of pesticides and preventing destruction of habitat.

Carnivores—Carnivores are a viable component of the southern landscape, whose management has changed significantly over the last several decades. The perception that carnivores must be eliminated is no longer widely held. These mammals contribute to ecosystem stability by controlling rodent populations.

There are few reliable density estimates for furbearers because they are secretive and difficult to census. Most are territorial. Population density is relatively low, reflecting their position at the top of the food chain. Two carnivores (the bobcat and river otter) are protected under the Convention for the International Trade of Endangered Species of Fauna and Flora (CITES) and are monitored closely by States that allow harvest of these species (Leopold and Chamberlain 2001).

The diet of carnivores is primarily composed of other animals. Bobcats, river otters, weasels, and mink characteristically have diets in which animal material exceeds 95 percent. The amounts of fruits, berries, and seeds vary with seasonal availability. For example, gray and red fox foods change from animal foods in the fall and winter to invertebrates and fruits during spring and summer.

Each species is associated with specific habitats that provide required food, water, and cover. Often, areas that are diverse in vegetative composition, structure, and seral stage are inhabited by a diversity of these mammals. A substantial number of carnivores depend on forested ecosystems to provide one or more habitat requirements. Mosaics of cover types and the ecotones between successional stages enhance prey and other food diversity. The structural components important to many mammals include mature trees, standing dead trees, woody debris, and patchy understories. Structural diversity and decaying trees provide suitable cover and foraging habitat.

Habitat quality determines the stability of these populations, while habitat loss is the primary threat to these species. Habitat modification influences species distribution and abundance. Forest clearing, grassland conversion, irrigation, and wetland drainage have improved habitat for some species and damaged habitat for others. The expanded range of the coyote throughout the South resulted from urbanization and the removal of large predators such as red wolves and Florida panthers.

Species with restrictive habitat requirements are vulnerable to losses of habitat. The swift fox depends on native shortgrass prairie communities; its range has become restricted due to the conversion of prairies into cultivated fields. Mammals associated with wetland habitats are not very resilient to habitat modification. For example, river channelization reduces habitat suitability for river otters (Allen 1988).

Large mammals such as the red wolf, Florida panther, and black bear have extensive home ranges. The maintenance of a mosaic of vegetation types and multiple seral stages supports prey populations and the food-producing plants that comprise the diet of these species. In contrast, the majority of carnivores depend on much smaller geographic areas. These species rely on a diversity of cover types in relatively close proximity to provide seasonal cover and food. Red foxes, gray foxes, and weasels are associated with early to mid-successional vegetation and the ecotones between these communities. Management that maintains fencerows, shelterbelts, and riparian vegetation will benefit these species and enhance their distribution.

The elimination of woody debris influences small mammal populations and makes them easier prey for associated predators. Timber harvest and prescribed burning change vegetation composition and enhances understory growth. However, timber removal may harm other mammals that require mature forest. In some cases, the protection of critical habitat may be the preferred management strategy.

Conservation of wetland carnivores centers on prevention of wetland degradation. Vegetative structure, surrounding land use, water quality, and cover diversity influence habitat quality for these mammals. For example, the manipulation of water levels and the planting of desired vegetation can enhance habitat. The maintenance of water availability and prey species also improves habitat potential. Debris and structural diversity along shorelines enhance prey availability for river otters. The removal of aquatic shoreline vegetation reduces availability of prey for mink.

Important habitat features for carnivores as well as other mammals occurring in the South are summarized in table 5.14. Detailed information for selected species is presented in the following section.

Species accounts: beaver—This species was extirpated from most of its southern range by the 1950s due to extensive trapping that began in the 18th century. Restocking programs

Table 5.14—Important habitat components and associated management guidelines for selected mammals in the South (continued)

Species	Key components of habitat	Management guidelines
Raccoon	Wetlands, riparian habitats, suitable den sites and winter food.	Preserve wetlands and riparian areas; maintain snags or diseased trees for den sites; encourage mast species; maintain fencerows.
Red fox	High degree of habitat edge; interspersion of mosaic of woodland, shrubland, cropland, and grassland habitat.	Maintain woodlots in agricultural areas to enhance vegetation diversity; maintain fencerows for travel corridors; encourage softmast production.
Red squirrel	Dense or clumped stands of mature forest; multi-storied stands; suitable nest sites; sufficient shade for cone storage.	Maintain large deciduous trees with cavities; preserve densely branched trees; provide clumped stands near mature conifers with interlocking crowns.
Ringtail cat	Rocky, brushy areas, talus slopes or wooded habitats in close proximity to water.	Maintain riparian vegetation in association with draws and ridgelines as travel corridors.
River otter	Water quality; permanent surface water, vegetative cover adjacent to wetlands; structural cover to provide foraging and den sites.	Maintain vegetative cover adjacent to wetlands; increase pool to riffle ratios; ensure water permanence; encourage beaver establishment.
Spotted/striped skunks	Ecotones between forest/shrubland and agricultural lands; riparian areas in arid regions.	Maintain woodlots in agricultural areas to enhance vegetation diversity; maintain fencerows for travel corridors; encourage softmast production.
Swift fox	Mid to shortgrass prairie habitats suitable to support an adequate prey base.	Establish vegetative communities to support prey base; maintain interspersion of grassland communities with agricultural lands.

Source: Adapted from Allen (1988).

in Louisiana, Mississippi, Alabama, Florida, Georgia, Oklahoma, Virginia, Arkansas, and North and South Carolina have led to viable populations across most of the South (Jones and Leopold 2001).

Beavers use freshwater habitats such as ponds, small lakes, and streams. Slow-moving streams and creeks with proximity to trees and shrubs that provide a food source are important. Beaver damming can flood forests, causing substantial economic impact from prolonged flooding. However, beavers create a complex successional mosaic of aquatic and terrestrial habitats that enrich landscape diversity. The creation of wetlands positively influences ground water, water quality, structural diversity, and erosion resistance. Beaver impoundments create favorable conditions for fish, birds, and amphibians. Beaver ponds on intermittent streams provide aquatic habitat conducive to the river otter.

River channelization significantly affects habitat quality by reducing amounts of riparian vegetation, macroinvertebrates, and fish biomass. The modification of river flow rates also reduces the number of islands occurring in the channel, impacting potential den habitat.

Species accounts: black bear—Black bears historically ranged over most of the South. Habitat loss, fragmentation, and unrestricted harvest have significantly changed their distribution and abundance.

Their current distribution is restricted to relatively undisturbed forests in the Appalachian Mountains and the Interior Highlands of Arkansas and in scattered coastal areas from Virginia to Louisiana (Vaughn and Pelton 1995). Populations appear to be secure and increasing in parts of Virginia, Tennessee, North Carolina, northern Georgia, and northern South Carolina, where they support regulated hunting seasons. In Tennessee, the species is known only from the mountains in the eastern part of the State (Chapman and Laerm, in press). In Kentucky, the black bear is designated as a species of special concern. Texas biologists indicate there is no resident breeding population there.

Two subspecies are of special concern. The Louisiana black bear is designated as threatened on the Federal species list and as endangered by the States of Mississippi, Louisiana, and Texas. The Florida subspecies is listed as threatened by the Florida Game and Fresh Water Fish Commission. Until recently, this subspecies was considered for protection under the Federal Endangered Species Act. Both subspecies populations are restricted to islands of public land and inaccessible areas of bottomland forest.

Black bears inhabit diverse forest habitats and are often found in oak-hickory and mixed mesophytic forests. Forested areas of 150 to 300 square miles with limited human intrusion are needed to sustain viable populations. In coastal areas, the species occupies pocosins, hardwood bottomlands, Carolina bays, mixed hardwood hammocks, cypress swamps, pine flatwoods, and sand pine scrub. Black bears need dense understory cover, such as laurel thickets and greenbriar, to provide refuge cover in the Coastal Plain.

Adequate denning cover is a necessary component of black bear habitat in the South. Such cover includes cavities in large trees, logs, stumps, rock outcroppings, and impenetrable thickets. Females and cubs are very susceptible to disturbance. Black bears need secure corridors to make seasonal movements for food, for dispersal of younger animals, and for movement by males during the breeding season (Pelton 2001).

The diet of black bears is primarily hard and soft mast, including berries, nuts, acorns, wild cherries, and grapes, as well as invertebrates. In some areas, bears feed on agricultural crops such as corn, wheat, or soybeans. Black bears will occasionally eat opossums, armadillos, feral pigs, raccoons, and young white-tailed deer.

The seasonal variations in availability of soft and hard mast influence shifts in home range to locate these foods. State biologists indicate that during periods of drought and food scarcity, bears further disperse and become victims of vehicular accidents, nuisance control, and illegal hunting.

Bear populations in the Southern Appalachians have been monitored since the 1960s. Although bear populations have increased during this period, the illegal trade in bear gall bladders has raised concerns about the effect of poaching. Because bears have low reproductive rates, their populations recover slowly from losses.

Habitat degradation continues to threaten black bears in the South. Forest fragmentation and the conversion of forests to agriculture, urban development, and pine monocultures restricts available habitat (Pelton 2001). The fragmented nature of black bear populations in the Coastal Plain may contribute to a loss of genetic diversity. As the human population in the South continues to expand into bear habitat, increased incidents of road kills are being reported in North Carolina, Tennessee, and Florida. As people settle into established bear ranges, increased human-bear interactions are inevitable. Poaching and increased access capabilities can result in overexploitation.

Components of black bear management include hunting access, habitat, protection, nuisance control, education, and research (Pelton 2001). Access can be restricted through road gating, designation of no-hunting zones, and provision of escape cover. Habitat management includes oak enhancement, protection of old growth (for den trees), and management of forest openings for soft mast production. The establishment of black bear sanctuaries and viable corridors on public land has protected bears in the region (Vaughn and Pelton 1995). Texas has proposed the establishment of bear "recovery zones" through a partnership among Federal and State agencies, forest industry, and other owners of large parcels of timberland. Stringent law enforcement also is required to reduce illegal hunting. Finally, State biologists suggest that education of the general public is critical to increase awareness and acceptance of regulations such as those that discourage feeding of bears.

Species accounts: bobcat—Bobcats are found throughout the South with the exception of north-central Kentucky, coastal Louisiana, and eastern Virginia (Leopold and Chamberlain 2001). Population density varies according to habitat type and prey density.

Bobcats use several habitats, preferring areas with dense understory vegetation that supports prey populations. A mixture of mature and early successional forest habitats is best. Other habitats include agricultural fields and pastures. Home ranges of bobcats throughout the Southeastern United States range from less than 740 acres to 17,830 acres. Home ranges may reflect road avoidance. Important prey species include rabbits and various rodents, opossum, game birds, and snakes (Chapman and Laerm, in press).

There are no major threats to bobcats in the South due to their wide distribution and ecological tolerance. Potential risks include overharvest by trapping, forest fragmentation, and road construction.

Species accounts: Carolina northern flying squirrel and Virginia northern flying squirrel—These two endangered subspecies inhabit high-elevation sites in the Southern Appalachians. The Carolina squirrel occurs in isolated locations in North Carolina and Tennessee, while the Virginia subspecies is in Virginia and West Virginia. The disjunct distribution of these subspecies in the Southern Appalachians suggests they are relicts that have become isolated in small patches of suitable habitat by changing climatic and vegetation conditions since the last Ice Age (U.S. Fish and Wildlife Service 1990a).

Flying squirrels are associated with high-elevation boreal habitats, especially spruce-fir and northern hardwood forests (Fridell and Litvaitis 1991). They occur in conifer-hardwood ecotones consisting of red spruce and fir associated with mature beech, yellow birch, maple, and several other species. Widely spaced, mature trees and snags provide cavities for nesting. Understory components do not appear to be important components of northern flying squirrel habitat (U.S. Fish and Wildlife Service 1990a).

Their diet consists of lichens, fungi, seeds, fruit, staminate cones, and insects. Periodic dependence on certain species of fungi may be a factor in restricting the species to high-elevation, mesic habitats (U.S. Fish and Wildlife Service 1990a).

The limited range of this species makes it vulnerable to natural and human-related impacts. Isolated populations suffer from insufficient gene pools. Other concerns include habitat destruction, insect pests such as the balsam woolly adelgid and the gypsy moth, recreational use, acid rain (which contaminates their mycorrhizal food source), and heavy metals (lead, copper, nickel, zinc, and manganese) in forest litter and soil (U.S. Fish and Wildlife Service 1990a).

Conservation strategies include determination of species distributions, protection of occupied sites from human-related disturbance, and implementation of habitat management guidelines on national forests and parks.

Species accounts: coyote—The distribution of coyotes has extended into the South during the past few decades in response to the elimination of gray and red wolves from their former ranges. Prior to 1970, red wolves were common throughout the South, but trapping and poisoning eliminated free-ranging populations. Gray wolves also once inhabited Kentucky, Tennessee, Virginia, and North Carolina. Removal of these two species contributed to coyote expansion. Leopold and Chamberlain (2001) indicate that coyote populations have expanded throughout the South, with the exception of southern peninsular Florida. The current population density of coyotes is unknown.

Coyotes occupy a broad range of habitats and occur in grassland, forest, agricultural fields, and urban areas. In the South, this species has been observed in open fields, brushlands, thickets, young forest, and forest-edge habitats. Habitat use by coyotes in the South is diverse and reflects their opportunistic feeding habits.

Their diet includes rabbits, small mammals, ground-nesting birds and their eggs, amphibians, lizards, fish, snails, crustaceans, insects, carrion, fruits, and plant roots (Chapman and Laerm, in press).

There are no known threats to coyote survival in the region. Animal damage control programs in the Western United States have been unsuccessful.

Species accounts: Florida panther—The Florida panther, one of 30 subspecies presently recognized, is the only subspecies of mountain lion remaining in the South. The species originally ranged from eastern Texas eastward through Arkansas, Louisiana, Mississippi, Alabama, Florida, Georgia, and portions of Tennessee and South Carolina. Due to large-scale habitat destruction and indiscriminant shooting, panthers were extirpated throughout most of their range by the early 1900s. Although periodic sightings are reported in remote areas of selected States, it is unlikely that viable populations exist outside of Florida. Currently, the population is estimated at between 20 and 50 animals.

Panthers prefer large remote tracts that are typically heavily vegetated and have minimal human disturbance. These animals use highly diverse habitats including hardwood hammocks, saw-palmetto woodlands, sawgrass prairies, cypress strands, and oak-pine woodlands. Home ranges average 200 square miles for males and 75 square miles for females.

Panthers subsist on a variety of mammalian prey, particularly white-tailed deer and feral hogs. In the northern portion of its range, feral hogs constitute the bulk of the diet, whereas white-tailed deer are more important in the southern portion. Panthers also readily take raccoons, armadillos, rabbits, and other small animals (Clark 2001).

Loss of habitat is the greatest threat to viable panther populations, but illegal shooting and highway collisions also are major problems. Off-road vehicle traffic has increased, making accessible large areas that formerly had been isolated wilderness. Intolerant of human disturbance, panthers are sensitive to habitat fragmentation stemming from road construction, agricultural development, and urban expansion. Other threats include parasites, diseases such as feline distemper and upper respiratory infections, and inbreeding depression. Panther populations are losing genetic diversity by 3 to 7 percent per generation; at this rate, extinction is probable in the next few decades (Clark 2001). Reduced prey base also is a concern. Panthers consume up to one deer or hog weekly. Due to habitat alteration, these prey animals may not be sufficiently abundant in Florida to meet this need.

Since panther habitat includes public and private land, management efforts must be coordinated. The key to panther conservation is habitat protection and acquisition of large, interconnected blocks of woodland. The recovery plan recommends: (1) enhancing existing populations through genetic management including captive breeding programs and genetic restoration; (2) protecting and managing existing habitat, including prescribed burning and exotic plant control; (3) establishing public support by educating private landowners; and (4) reintroducing panthers into areas of suitable habitat (U.S. Fish and Wildlife Service 1995). Potential release sites include the lower Coastal Plain of Alabama, Mississippi, Arkansas, and Louisiana and the lower Apalachicola River in Florida.

Species accounts: gray fox and red fox—Foxes occur throughout Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, and eastern Texas. The gray fox does not occur in coastal Louisiana or the Florida Keys, while the red fox does not inhabit the southern Florida peninsula. The population density of red and gray foxes in the South is not known.

Foxes occur in a variety of habitats. The red fox prefers open habitats including old fields, shrublands, pastures, and mixed hardwood forests; the gray fox is more of a woodland-edge species. Both prefer areas supporting an interspersion of different vegetative communities. Hollow logs, trees, brush piles, and rock outcrops are often used as dens. Patterns of habitat use change seasonally with food availability.

Foxes are opportunistic feeders. During the fall and winter, small animals comprise the bulk of their diet. Common prey includes rabbits, voles, mice, wood rats, and various birds (Fritzell 1987). Fruits, berries, arthropods, and amphibians are added to the diet during the summer and fall.

The planting of blackberry, honeysuckle, and other soft mast enhances fox habitat. Prescribed burning maintains old fields and forests in desirable condition. Cultivation of trees that produce hard mast also is important.

Trapping, hunting, road kills, and rabies are the major causes of fox mortality. The decline in red fox populations in some areas of the South has been attributed to interspecific interaction with coyotes.

Species accounts: gray bat—The U.S. Fish and Wildlife Service lists this species as endangered. The species distribution in the South includes the cave regions of Alabama, Arkansas, Kentucky, and Tennessee, but a few occur in Florida, Georgia, northeastern Oklahoma, Mississippi, Virginia, and North Carolina. Bat populations have become fragmented during the past few decades (Harvey and Saugey 2001). Ninety-five percent of gray bats hibernate in 10 caves.

Gray bats are year-round cave residents but usually occupy different caves in summer and winter. During the winter, they hibernate primarily in deep vertical caves with large rooms acting as cold-air traps (42 to 52 °F). Maternity roosts are established in warm, humid caves that provide domed ceilings capable of trapping body heat from bat clusters. Less than 5 percent of available caves in the South have the right properties of temperature, humidity, and structure to make them suitable for gray bat occupation (Harvey and Saugey 2001).

Like many bats, this species hunts for insects above forested rivers and streams. Moths, beetles, flies, mosquitoes, mayflies, and other insects are important in the diet.

The primary reasons for population declines include disturbance, vandalism, cave destruction, and pollution. Disturbance during hibernation depletes energy reserves and increases mortality. Conservation actions focus on the protection of occupied caves and appropriate management of the surrounding forest and aquatic foraging sites. Cave gates and fences must be properly designed to allow bat movement. This species is recovering due to the protection of four critical caves (Harvey and Saugey 2001).

Species accounts: Indiana bat—The Indiana bat is listed as endangered by the U.S. Fish and Wildlife Service. This species is known to occur throughout much of the Midwestern and Eastern United States; however, it has been virtually eliminated from much of its former range. The bat occurs in the northern portions of the South, including Tennessee, Virginia, and Kentucky. Isolated sightings have been made in the Carolinas, Alabama, and Mississippi. The current population of the species nationwide is estimated at 400,000 individuals; approximately 85 percent of the population is limited to 7 caves (Harvey and Saugey 2001).

During the summer, maternity roosts are established between exfoliating bark and the bole of snags, in hollow trees, or in live trees. Male bats often use pitch pine and shortleaf pines. These bats need winter caves or mines retaining stable temperatures of 39 to 46 °F and standing water that maintains relative humidity. The bats forage above streams, water bodies, and open areas. Riparian, upland, and floodplain forests are also used.

During hibernation, the Indiana bat is extremely vulnerable to any type of disturbance. Factors contributing to its decline include cave disturbance, improperly designed cave gates, and intentional killing. Habitat loss stemming from deforestation and stream channelization is another concern. Natural elements that imperil the species include flooding of occupied caves, exposure to freezing temperatures, and cave ceiling collapse. Forest management centers on the provision of summer roost sites and foraging habitat.

Species accounts: mink—Mink occur throughout the South, with the exception of central Florida and western Texas. They are common in the marshes along the Atlantic and Gulf Coasts and are widespread in Virginia, North Carolina, and South Carolina (Chapman and Laerm, in press). Population densities vary with the type and permanence of aquatic habitat and are influenced by climate, trapping, and intraspecific interaction.

Mink require wetland habitats, such as marshes, swamps, riverbanks, and streams. Habitat use varies by geographic area and season. There are no published data on mink home ranges or habitat use patterns in the South. Muskrats, mice, and lagomorphs are the preferred prey; mink diets also include birds, amphibians, crawfish, and fish.

Habitat degradation as a result of wetland alteration is a concern in the South. Mink are vulnerable to environmental contaminants, particularly mercury and pesticide residues, concentrated in prey foods. The prevention of high levels of environmental contaminants is needed to ensure habitat quality for this species.

Species accounts: Ozark big-eared bat and Virginia big-eared bat—These two subspecies are endangered and are federally protected throughout their respective ranges. Only a few caves in eastern Oklahoma, Arkansas, and Missouri are known habitats for the Ozark subspecies. The Virginia bat inhabits eastern Kentucky, Virginia, North Carolina, and West Virginia, but fewer than five caves are known to contain nursery colonies of this subspecies (Harvey and Saugey 2001).

The bats inhabit caves in limestone and schist formations throughout the year. Adjacent land use does not appear to influence cave selection. Roosting sites are often near mature bottomland and upland hardwood forests adjacent to water. Important habitat features include hollow trees, loose bark, and rock shelters. The bats prefer relatively cold, well-ventilated locations and are often found near cave entrances when hibernating. Big-eared bats forage in forested areas among the canopies of large trees, consuming beetles, flies, mosquitoes, gnats, moths, and many other insects.

The species is vulnerable to pesticides and human disturbance of their caves. They are easily disturbed and quick to take flight. Conservation actions center on the protection of roosting sites and the retention of hollow trees.

Species accounts: red wolf—The red wolf is an endangered species. The original distribution of the wolf included southern Illinois, Indiana, and Pennsylvania south to Florida and west to southern Texas. Indiscriminate trapping, hunting, and poisoning, loss of habitat, and expansion of urban and agricultural areas contributed to the demise of this species. The last remnant populations in the wild were verified in southern Louisiana and Texas in the 1970s.

In the late 1980s, efforts were made to translocate wolves to five locations: Alligator River National Wildlife Refuge, North Carolina; Bull's Island, South Carolina; St. Vincent Island, Florida; Horn Island, Mississippi; and the Great Smoky Mountains National Park. Recent threats center on genetic dilution due to hybridization with wild dogs and coyotes.

Historically, the wolf was found in old-growth forests, pine forests, bottomland hardwood forests, coastal prairies, and marshes. Current information on wolf ecology is limited to studies in the coastal marshes of Texas and Louisiana during the 1960s and 1970s and to observations at restoration sites (Crawford and others 2001). Heavy vegetative cover along bayous and fallow fields is ideal habitat. Home ranges vary from 17 to 38 square miles, depending upon habitat and prey density. Red wolves require large tracts of land relatively free of human development, paved roads, and livestock.

Red wolves are opportunistic predators, preying upon feral pigs, white-tailed deer, nutria, eastern cottontails, swamp rabbits, marsh rice rats, and fox squirrels. They will also eat birds, rodents, frogs, and turtles. A diversity of prey is necessary for sustaining population levels.

The recovery plan objectives center on the achievement of population levels large enough to ensure genetic integrity (U.S. Fish and Wildlife Service 1989). Potential reintroduction sites are examined for biological factors (prey abundance, habitat types) and socioeconomic factors (agricultural practices, land ownership patterns, proximity of towns). Areas of at least 170,000 acres are required by this species. The absence of coyotes is preferable to avoid hybridization. Site considerations include the potential for wolf-livestock interaction and human disturbance. Public attitudes about wolves are significant factors in their recovery.

Species accounts: river otter—The river otter is listed as a threatened species in Tennessee and as a species of concern in Oklahoma and Virginia. Otters occur regionally in many habitats associated with waterways, and their numbers are increasing in some parts of the region. The species is increasing in abundance throughout Virginia, where it is most common in the Coastal Plain and Piedmont. It also is relatively common in western Tennessee. Reliable census procedures for the river otter have not been developed, and few researchers have attempted to estimate population levels.

River otters use a variety of aquatic habitats including coastal estuaries, marshes, and streams. Riparian and shoreline vegetation bordering waterways is an important component of river otter habitat. Beaver impoundments, submerged trees, and logjams provide shelter and foraging areas for otters. Otters feed primarily on fish; other foods include aquatic insects, birds, small mammals, snakes, and amphibians.

Threats to otter populations include the clearing of bottomland forests, wetland modification, and pollution of aquatic environments. Otters are frequently caught in traps intended for beaver; the low reproductive potential of the otter, and the restricted nature of its habitat make the species susceptible to overharvest. As a result of trapping pressure, the otter was given protection under the Convention on International Trade in Wild Species of Endangered Flora and Fauna.

Strict population monitoring is needed. Continued management includes the restoration of otter populations in Kentucky, Oklahoma, Tennessee, and North Carolina. Reintroduction in the Great Smoky Mountains National Park began in the 1980s, where otter populations were once extirpated.

Species accounts: white-tailed deer—Deer are widespread and relatively abundant throughout the Southern United States. Populations on some islands have declined. Deer populations have fluctuated dramatically since European settlement of the South. Populations in the past declined to critical levels because of intensive hunting, widespread agricultural clearing, and other habitat alteration. Populations have rebounded during the last several decades due to farm abandonment, lower hunting pressure, and the extirpation of large predators. In some locations, populations are increasing to levels that make the species a pest.

The endangered Key deer is restricted to the lower Florida Keys. Four other subspecies of concern occur on Sapelo and Blackbeard Islands in Georgia and on Hilton Head Island, Bull's Island, and Hunting Island in South Carolina.

White-tailed deer use a wide range of habitat types and benefit from a mosaic of wetlands, forests, farmland, and early successional habitats. Preferred foods are acorns, blueberries, sumac, grapes, hawthorns, common persimmons, dwarf palmettos, and blackberries.

There are no threats to the survival of the white-tailed deer in the region.

However, coastal development has contributed to the decline of the island subspecies. Key deer are threatened by habitat loss, poaching, vehicular accidents, and attacks by feral dogs (White and others 1998).

Discussion and Conclusions

Based on listings from the U.S. Department of Interior (2000), every Southern State contains species that are under Federal protection (figs. 5.7 and 5.8). The endangered category refers to species that are in danger of extinction in the foreseeable future throughout significant portions of their range. The threatened designation is assigned to species likely to become endangered in the future. Status determinations are based on modification or restriction of habitat, commercial overutilization, disease or predation pressure, the inadequacy of existing regulations, and other factors affecting continued existence.

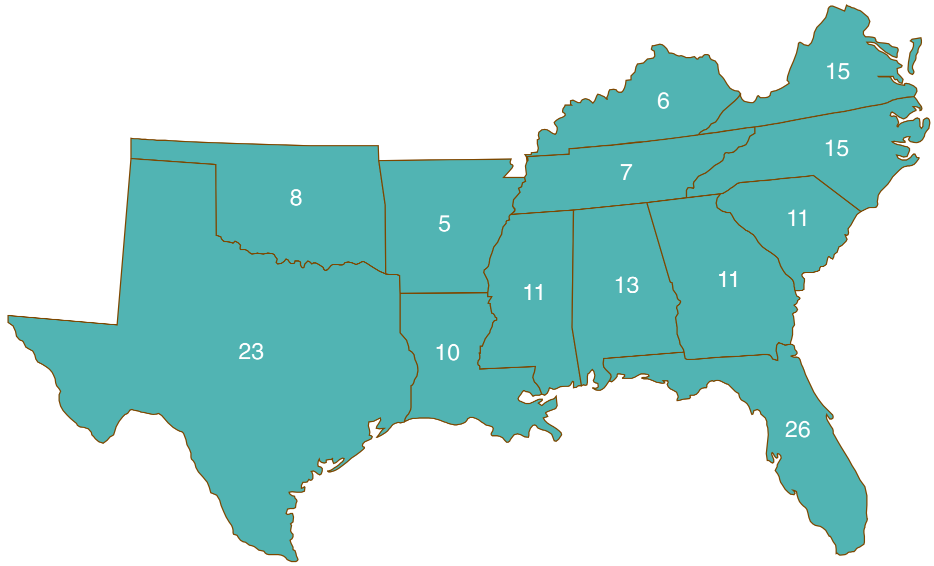

Figure 5.7—The distribution of terrestrial vertebrates listed as endangered throughout the South (U. S. Department of the Interior 2000).

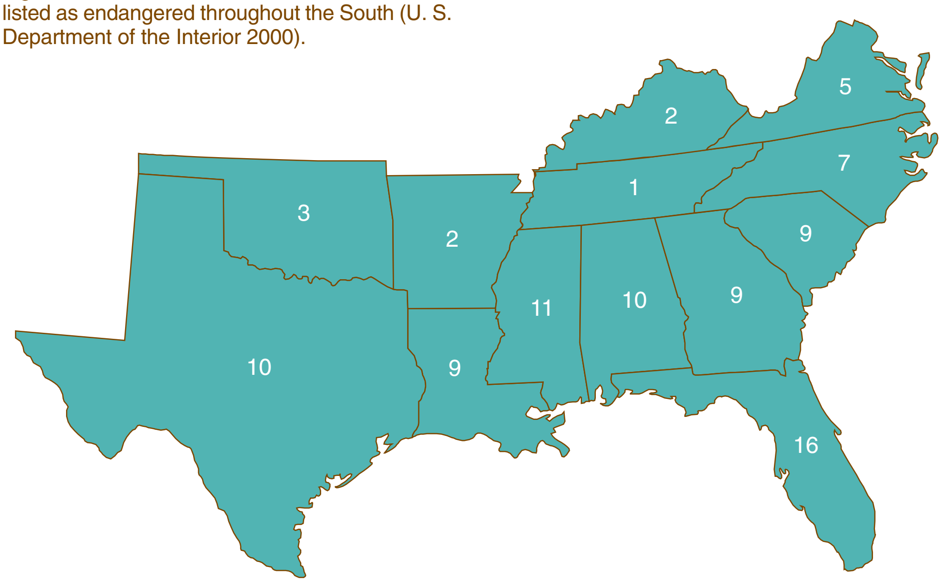

Figure 5.8—The distribution of terrestrial vertebrates listed as threatened throughout the South (U. S. Department of the Interior 2000).

There are a number of different explanations for the number of listed species in a State. A State may support many unique habitats with high species richness. Texas is the largest State in the South in both area and species richness. The wide range of environmental conditions and diverse habitats that occur in Texas also support the second highest level of protected species. Larger areas on average support a greater diversity of habitats and a wider variety of species, listed or otherwise.

A species that has been extirpated from adjacent States may persist in areas that support the last remnants of suitable habitat. For example, the red wolf formerly ranged from Texas to the Atlantic Coast. It presently occurs in North Carolina, Tennessee, and Florida, where it has been reintroduced. The Florida panther, another far-ranging mammal, once occurred throughout the region. This species presently is found solely in isolated areas in Florida.

A high number of listed species may also reflect an inherently fragile fauna, such as that in the high-elevation habitats of the Southern Appalachians. It also may reflect a high level of endemic species, such as those associated with scrub habitats of central Florida. Finally, the number of listed species in a State may reflect deteriorating environmental conditions and modification of natural ecosystems, such as longleaf pine forests. Each of these factors contributes to the number of federally protected species in a State. Each reason has bearing on how habitat is managed and protected.

Various natural and human-caused factors contribute to a species imperilment. Some species occur in a very localized geographic area or in a few isolated areas of suitable habitat. These narrowly restricted species tend to be vulnerable to local disturbances that would have little effect on species with wide ranges. The summits and the bogs of the Southern Appalachian Mountains support some highly vulnerable species, such as the northern flying squirrel and the water shrew.

Scattered populations in fragmented habitat can be at risk. They become demographically isolated because they have little or no interaction with other populations. These isolated populations are prone to inbreeding depression and genetic drift, which inhibit viability. Localized populations are also vulnerable to catastrophic events such as floods, droughts, and fires.

Many species have declined because of habitat alteration stemming from human activities. These species are unable to adapt due to changes in habitat features such as vegetative composition and structure and water quality.

Several factors repeatedly surface as threats to terrestrial vertebrates. The most prevalent factor is human development for urban, industrial, and agricultural land uses. Environmental contamination is a second prominent threat, especially in the Southern Appalachians and along the gulf coast. Coastal development contributes to endangerment on both the gulf and Atlantic Coasts. Exploitation occurs primarily on shorelines and in coastal wetlands. Other factors contributing to species endangerment include fire suppression, introduction of exotic species, and the loss of aquatic and wetland habitats.

Habitat loss affects all species, including migrating birds, wide-ranging mammals, and species like the gopher tortoise, which cannot disperse over long distances. Imperiling factors influence species unequally. Turtles are especially vulnerable to human exploitation for food and pets. Bats and snakes are heavily impacted by human disturbance. Beavers and river otters are imperiled by channel modification and impoundments. Environmental contaminants impact the spruce-fir forests used by the northern flying squirrel and the high-elevation mountain streams occupied by a diversity of salamanders. The use of agricultural pesticides affects gamebirds, bats, and amphibians. Wetland alteration affects the Mississippi sandhill crane, mink, and several species of frogs and toads. Lastly, coastal development negatively influences the habitat of the southeastern beach mice, wood storks, marine turtles, and Key deer.

Often, it is difficult to identify a specific factor responsible for the changes observed in a species population. For example, many migratory birds that breed in the South are also dependent on wintering habitats outside of the country. Neotropical migrants are influenced by the loss of wintering habitat in the tropics, while wintering mallard populations are affected by breeding habitat in the prairie pothole region. Therefore, it is vital to understand the temporal and spatial context in which a species occurs. Local changes in the population of species may be a result of dramatic changes in habitat occurring elsewhere.

Maintaining viable populations of southern vertebrate species requires the protection of critical habitat as well as the proactive management of other habitat. Public lands have a key role in species conservation (chapter 1). In some instances, protecting sensitive habitats from further alteration is the best management action. In other instances, active enhancement may be the most appropriate action. For example, treatments may be needed to increase understory growth, create multiple seral stages, restore unique habitats, and control exotic species. Professional foresters, resource managers, and conservationists play an important role in this regard.

There have been notable success stories in managing southern vertebrates. Restrictions on pesticides have improved the status of bald eagles. Red-cockaded woodpeckers have benefited from the management of mature pine forests, provision of artificial cavities, and translocation efforts. River otters and beavers have been restored to areas they formerly inhabited. Alligator populations have rebounded because of management of harvest levels and the protection of wetlands. Many of these species have proven far more resilient and adaptable than once thought.

However, additional efforts are necessary to restore and enhance ecosystem integrity and resiliency on the southern landscape. Management plans should consider the assemblage of reptiles, amphibians, birds, and mammals. Herpetofauna have traditionally received less management attention than other vertebrates. Wetland buffers, travel corridors, and forest composition are important for their viability. Many species are long-lived and late maturing, and have restricted geographic ranges; their management requires different strategies than those used for birds and mammals. Management remains somewhat hindered, however, by the limited knowledge about the status of terrestrial vertebrates and their habitat relationships.

Land ownership patterns associated with the occurrence of southern species have management implications. Approximately 90 percent of the land in the South is privately owned. The protection and management of species habitats can no longer be relegated solely to public land. To be successful, comprehensive conservation strategies require the cooperation of private landowners. Cooperative forestry programs and county extension services are two sources of expertise that contribute to the management of private lands.

In the past few decades, residential and industrial areas have grown rapidly to serve an expanding southern population. Although the extent of southern forests has remained relatively stable in recent years, human and wildlife interactions have increased, and they will continue to do so. Public perceptions about particular species can hinder or foster conservation efforts, highlighting the role of environmental education.

One role for wildlife professionals in the South is to identity the species that face imperilment, determine the actions necessary to eliminate those threats, and then take the necessary actions. Another role is to provide and manage habitat for several game species. The many species inhabiting the southern landscape have a wide variety of habitat requirements; an understanding of these requirements can lead to management plans that promote viable populations and habitat enhancement.

Needs for Additional Research

Further research is needed on the status, distribution, population trends, and habitat requirements of many southern species. Although there are standardized inventories for bird and game species across the region, there is a lack of comparable monitoring protocols for many other species. The importance of regional monitoring and long-term research cannot be overstated.

Additional data are necessary to examine the attributes that make some species associations resistant or resilient to disturbance. We need to understand why some associations are more fragile than others. We also need to know how to mitigate negative disturbance factors.

Habitat relationships of listed and imperiled species need further study.

Examination of the connections between landscape patterns, land uses, and the presence or absence of concern species also would prove beneficial. The establishment of regional databases and standardized sampling protocols for monitoring trends of terrestrial species across all public lands also is needed.

A profound need exists for the coordination of regional inventories on public lands to monitor the status and trends of reptile and amphibian populations. Assemblages associated with specific habitats need to be identified.

Further research is necessary on the distribution, ecology, and life history of herpetofaunal species and communities. In particular, additional data are needed on species such as the flatwoods salamander, gopher frog, southern hognose snake, and pine snake. This basic information is essential to developing land management programs for these species.

Additional research is needed to determine the impact of natural and human-caused factors on the development and environment of amphibians. Additional information needs include the identification of critical habitats and migration routes. The concern over amphibian declines highlights the lack of basic information about these species.

The ecology of furbearers, such as mink and weasel, is poorly understood, as are the potential impacts on other carnivores resulting from coyote expansion throughout the South. Basic ecological data are needed on free-ranging red wolves to address the challenges of restoration. The degradation of river otter habitat suggests the need for continued monitoring to ensure population viability. Careful monitoring of black bear populations also is essential to ensure their continued existence over the long term.

Finally, there is a paucity of information about specific habitat needs for several bat species and the influence of different silvicultural treatments on their populations.

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Literature Cited

Allen, A.W. 1988. The relationship between habitat and furbearers. In: Novak, M.J.; Baker, A.; Obbard, M.E.; Malloch, B., eds. Wild furbearer management in North America. Toronto, ON: Ministry of Natural Resources: 164-179.

Bailey, M.A. 1995. The Red Hills salamander. Alabama's Treasured Forests. 14(1): 28-29.

Barclay, R.M.; Brigham, R.M. 1998. Hide and seek: in search of forest bats. Bats. 16(1): 3-7.

Boyce, S.G.; Martin, W.H. 1993. Introduction: the southeastern setting. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: upland terrestrial communities. New York: John Wiley: 1-46.

Brown, L.E. 1975. The status of the near-extinct Houston toad (*Bufo houstonensis*) with recommendations for its conservation. Herpetological Review. 6: 37-40.

Buckner, E. 1989. Evolution of forest types in the Southeast. In: Waldrop, T.A., ed. Pine-hardwood mixture: a symposium on management and ecology of the type. Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 17-33.

Burke, V.J.; Gibbons, J.W. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. Conservation Biology. 9: 1365-1369.

Bury, R.B.; Dodd, C.K., Jr.; Fellers, G.M. 1980. Conservation of the amphibia of the United States: a review. Resour. Publ. 134. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 34 p.

Campbell, H.W.; Moler, P.E. 1992. Short-tailed snake. In: Moler, P.E., ed. Rare and endangered biota of Florida. Amphibians and reptiles. Gainesville, FL: University of Florida Press: 150-153. Vol. 3.

Chapman, B.; Laerm, J. [In press]. Land manager's guide to the mammals of the South. Chapel Hill, NC: The Nature Conservancy. 360 p.

Christman, S.P. 1992. Sand skink. In: Moler, P.E., ed. Rare and endangered biota of Florida. Amphibians and reptiles. Gainesville, FL: University of Florida Press: 135-140. Vol. 3.

Clark, J.D. 2001. Florida panther. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 234-239.

Conant, R.; Collins, J.T. 1991. A field guide to reptiles and amphibians of Eastern and Central North America. 3rd ed. Boston: Houghton Mifflin Co. 450 p.

Congdon, J.D.; Dunham, A.F.; Van Loben Sels, R.C. 1994. Demographics of common snapping turtles (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. American Zoology. 34: 397-408.

Crawford, B.A.; Lucash, C.F.; Henry, V.G. 2001. Red wolf. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 240-247.

Delcourt, P.A.; Delcourt, H.R.; Morse, D.F.; Morse, P.A. 1993. History, evolution, and organization of vegetation and human culture. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 47-79.

Dickson, J.G. 2001. Early history. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 20-30.

Dobie, J.L.; Bagley, F.M. 1988. Recovery plan for the Alabama red-bellied turtle (*Pseudemys alabamensis*). Tech. Rev. Draft. Atlanta: U.S. Fish and Wildlife Service. 20 p.

Dodd, C.K., Jr. 1991. The status of the Red Hills salamander, *Phaeognathus hubrichti*, Alabama, U.S.A., 1976-1988. Biological Conservation. 55: 57-75.

Dodd, C.K., Jr. 1995a. Marine turtles in the Southeast. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 121-123.

Dodd, C.K., Jr. 1995b. Reptiles and amphibians in the endangered longleaf pine ecosystem. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 129-131.

Echternacht, A.C.; Harris, L.D. 1993. The fauna and wildlife of the Southeastern United States. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 81-116.

Ernst, C.H.; Barbour, R.W.; Lovich, J.E. 1994. Turtles of the United States and Canada. Washington, DC: Smithsonian Institution Press. 578 p.

Flather, C.H.; Knowles, M.S.; Kendall, I.A. 1998. Threatened and endangered species geography: characteristics of hot spots in the conterminous United States. BioScience. 48(5): 365-376.

Fridell, R.A.; Litvaitis, J.A. 1991. Influence of resource distribution and abundance on home-range characteristics of southern flying squirrels. Canadian Journal of Zoology. 69(10): 2589-2593.

Fritzell, E.K. 1987. Gray fox and island gray fox. In: Novak, M.; Baker, J.A.; Obbard, M.E.; Malloch, B., eds. Wild furbearer management and conservation in North America. Toronto, ON: Ministry of Natural Resources: 409-420.

Fuller, M.R.; Henny, C.J.; Wood, P.B. 1995. Raptors. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 65-69.

Gibbons, J.W.; Buhlmann, K.A. 2001. Reptiles and amphibians. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 372-390.

Gibbons, J.W.; Burke, V.J.; Lovich, J.E. [and others]. 1997. Perceptions of species abundance, distribution, and diversity: lessons from four decades of sampling on a government-managed reserve. Environmental Management. 21: 259-268.

Guyer, C.; Bailey, M.A. 1993. Amphibians and reptiles of longleaf pine communities. In: Hermann, S.M., ed. The longleaf pine ecosystem: ecology, restoration, and management. Proceedings, Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 139-158.

Hall, R.J. 1995. Birds: overview. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 15-17.

Hamel, P.B. 1992. Land manager's guide to the birds of the South. Chapel Hill, NC: The Nature Conservancy. 417 p.

Harvey, M.J.; Altenbach, J.S.; Best, T.L. 1999. Bats of the United States. Little Rock, AR: Arkansas Game and Fish Commission. 64 p.

Harvey, M.J.; Saugey, D.A. 2001. Bats. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 359-371.

Healy, R.G. 1985. Competition for land in the American South: agriculture, human settlement, and the environment. Washington, DC: The Conservation Foundation. 333 p.

Hunter, W.C.; Dickson, J.G.; Pashley, D.N.; Hamel, P.B. 2001. Bird communities of southern forests. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 322-349.

Jones, J.; Leopold, B.D. 2001. Herbivorous furbearers. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 293-308.

Krusic, R.A.; Yamasaki, M.; Neefus, C.D.; Perkins, P.J. 1996. Bat habitat use in the White Mountain natural forest. Journal of Wildlife Management. 60: 625-631.

Kulhavy, D.L.; Conner, R.N., eds. 1986. Wilderness and natural areas in the Eastern United States: a management challenge. Nacogdoches, TX: Stephen F. Austin State University, School of Forestry, Center for Applied Studies. 416 p.

Laerm, J.; Ford, W.M.; Chapman, B.R. 2000. Conservation status of terrestrial mammals of the Southeastern United States. In: Chapman, B.R.; Laerm, J., eds. Fourth colloquium on conservation of mammals in the Southeastern United States. Occas. Pap. 12. Raleigh, NC: North Carolina Museum of Natural Sciences. Fall: 4-16.

Leopold, B.D.; Chamberlain, M.J. 2001. Carnivorous furbearers. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 248-277.

Lorimer, C.G. 2001. Historical and ecological roles of disturbance in Eastern North American forests: 9000 years of change. Wildlife Society Bulletin. 29(2): 425-439.

Lovich, J.E. 1995. Turtles. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 118-121.

Martof, B.S.; Palmer, W.M.; Bailey, J.R.; Harrison, J.R., Jr. 1980. Amphibians and reptiles of the Carolinas and Virginia. Chapel Hill, NC: University of North Carolina Press. 264 p.

Means, D.B. 1992. One-toed Amphiuma. In: Moler, P.E., ed. Rare and endangered biota of Florida. Amphibians and reptiles. Gainesville, FL: University of Florida Press: 34-38. Vol. 3.

Mitchell, J.C. 1994. The reptiles of Virginia. Washington, DC: Smithsonian Press. 352 p.

Moler, P.E. 1992a. American crocodile. In: Moler, P.E., ed. Rare and endangered biota of Florida. Amphibians and reptiles. Gainesville, FL: University of Florida Press: 83-89. Vol. 3.

Moler, P.E. 1992b. Bog frog. In: Moler, P.E., ed. Rare and endangered biota of Florida. Amphibians and reptiles. Gainesville, FL: University of Florida Press: 30-33. Vol. 3.

Moler, P.E. 1992c. Eastern indigo snake. In: Moler, P.E., ed. Rare and endangered biota of Florida. Amphibians and reptiles. Gainesville, FL: University of Florida Press: 181-186. Vol. 3.

Mount, R.H. 1986. Southern hognose snake, *Heterodon simus* (Linnaeus). In: Mount, R.H., ed. Vertebrate animals of Alabama in need of special attention. Auburn, AL: Auburn University, Alabama Agricultural Experiment Station: 34-35.

NatureServe. 2000. An online encyclopedia of life. [Database]. Version 1.4. Association for Biodiversity Information. http://www.natureserve.org/explorer/index.htm. [Date accessed: August, September, October, and December].

Noss, R.F.; LaRoe, E.T., III; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biol. Rep. 28. Washington, DC: National Biological Service. 58 p.

Palmer, W.M.; Braswell, A.L. 1995. Reptiles of North Carolina. Chapel Hill, NC: University of North Carolina Press. 412 p.

Partners in Flight. 2000. Physiographic area plans. [Database]. http://www.blm.gov/wildlife/pifplans.htm. [Date accessed: October].

Pashley, David N.; Beardmore, C.J.; Fitzgerald, J.A. [and others]. 2000. Partners in flight. Conservation of the land birds of the United States. The Plains, VA: American Bird Conservancy. 92 p.

Pelton, M.R. 2001. American black bear. In: Dickson, J., ed. Wildlife of the southern forests: habitat and management. Blaine, WA: Hancock House Publishing: 224-233.

Peterjohn, B.J.; Sauer, J.R.; Orsillo, S. 1995. Breeding bird survey: population trends 1966-1992. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 17-21.

Pierson, E.D. 1998. Tall trees, deep holes, and scarred landscapes: conservation biology and North American bats. In: Kunz, T.H.; Racey, P.A., eds. Bat biology and conservation. Washington, DC: Smithsonian Institution Press: 309-325.

Porras, L.; Wilson, L.D. 1979. New distributional records for *Tantilla oolitica* Telford (Reptilia, Serpentes, Colubridae) from the Florida Keys. Journal of Herpetology. 13: 218-220.

Reaser, J.K. 1996. The elucidation of amphibian declines: are amphibian populations disappearing? Amphibian and Reptile Conservation. 1: 4-9.

Reaser, J.K.; Johnson, P.T. 1997. Amphibian abnormalities: a review. Froglog. 24: 2-4.

Reichling, S.B. 1995. The taxonomic status of the Louisiana pine snake (*Pituophis melanoleucus ruthveni*) and its relevance to the evolutionary species concept. Journal of Herpetology. 29: 186-198.

Rudolph, D.C.; Burgdorf, S.J. 1997. Timber rattlesnakes and Louisiana pine snakes of the west Gulf Coastal Plain: hypothesis of decline. Texas Journal of Science. 49: 111-121.

Semlitsch, R.D.; Bodie, J.R. 1998. Are small, isolated wetlands expendable? Conservation Biology. 12: 1129-1133.

Speake, D.W.; Diemer, J.; McGlincy, J. 1982. Eastern indigo snake recovery plan. Atlanta: U.S. Fish and Wildlife Service. 23 p.

Stein, B.A.; Kutner, L.S.; Adams, J.S., eds. 2000. Precious heritage: the status of biodiversity in the United States. The Nature Conservancy. New York: Oxford University Press. 399 p.

Trani, M.K.; Brooks, R.T.; Schmidt, T.L. [and others]. 2001. Patterns and trends of early successional forests in the Eastern United States. Wildlife Society Bulletin. 29(2): 413-424.

Tuttle, M.D. 1995. Saving North America's beleaguered bats. National Geographic. 188(2): 37-57.

U.S. Department of the Interior, Fish and Wildlife Service. 2000. Southeast Region 4. http://endangered.fws.gov/wildlife.html. [Date accessed: October].

U.S. Fish and Wildlife Service. 1983. Red Hills salamander recovery plan. Atlanta: U.S. Fish and Wildlife Service. 23 p.

U.S. Fish and Wildlife Service. 1988. A recovery plan for the ringed sawback turtle, *Graptemys oculifera*. Atlanta: U.S. Fish and Wildlife Service. 28 p.

U.S. Fish and Wildlife Service. 1989. Red wolf recovery plan. Atlanta: U.S. Fish and Wildlife Service. 110 p.

U.S. Fish and Wildlife Service. 1990a. Appalachian northern flying squirrels (*Glaucomys sabrinus fuscus* and *Glaucomys sabrinus coloratus*) recovery plan. Newton Corner, MA: U.S. Fish and Wildlife Service. 53 p.

U.S. Fish and Wildlife Service. 1990b. Endangered and threatened species recovery program: report to Congress. [Washington, DC]: [U.S. Fish and Wildlife Service]. 406 p.

U.S. Fish and Wildlife Service. 1990c. Gopher tortoise recovery plan. Jackson, MS: U.S. Fish and Wildlife Service. 28 p.

U.S. Fish and Wildlife Service. 1995. Florida panther recovery plan. 2nd revision. Atlanta: U.S. Fish and Wildlife Service. 69 p.

Vaughan, M.R.; Pelton, M.R. 1995. Black bear. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 100-103.

White, P.S.; Wilds, S.P.; Thunhorst, G.A. 1998. Southeast. In: Mac, M.J.; Opler, P.A.; Puckett Haecker, C.E.; Doran, P.D., eds. Status and trends of the Nation's biological resources. Reston, VA: U.S. Department of the Interior, U.S. Geological Survey: 255-314. 2 vols.

Wilhide, J.D.; Harvey, M.J.; McDaniel, V.R.; Hoffman, V.E. 1998. Highland pond utilization by bats in the Ozark National Forest. Journal of the Arkansas Academy of Science. 52: 110-112.

Williams, M. 1989. Americans and their forests: a historical geography. New York: Cambridge University Press. [Number of pages unknown].

Wilson, L.A. 1995. Land manager's guide to the amphibians and reptiles of the South. Chapel Hill, NC: The Nature Conservancy. 360 p.

Woodward, A.R. 1995. Alligators in Florida. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. Our living resources: a report to the Nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, DC: U.S. Department of the Interior, National Biological Service: 127-129.

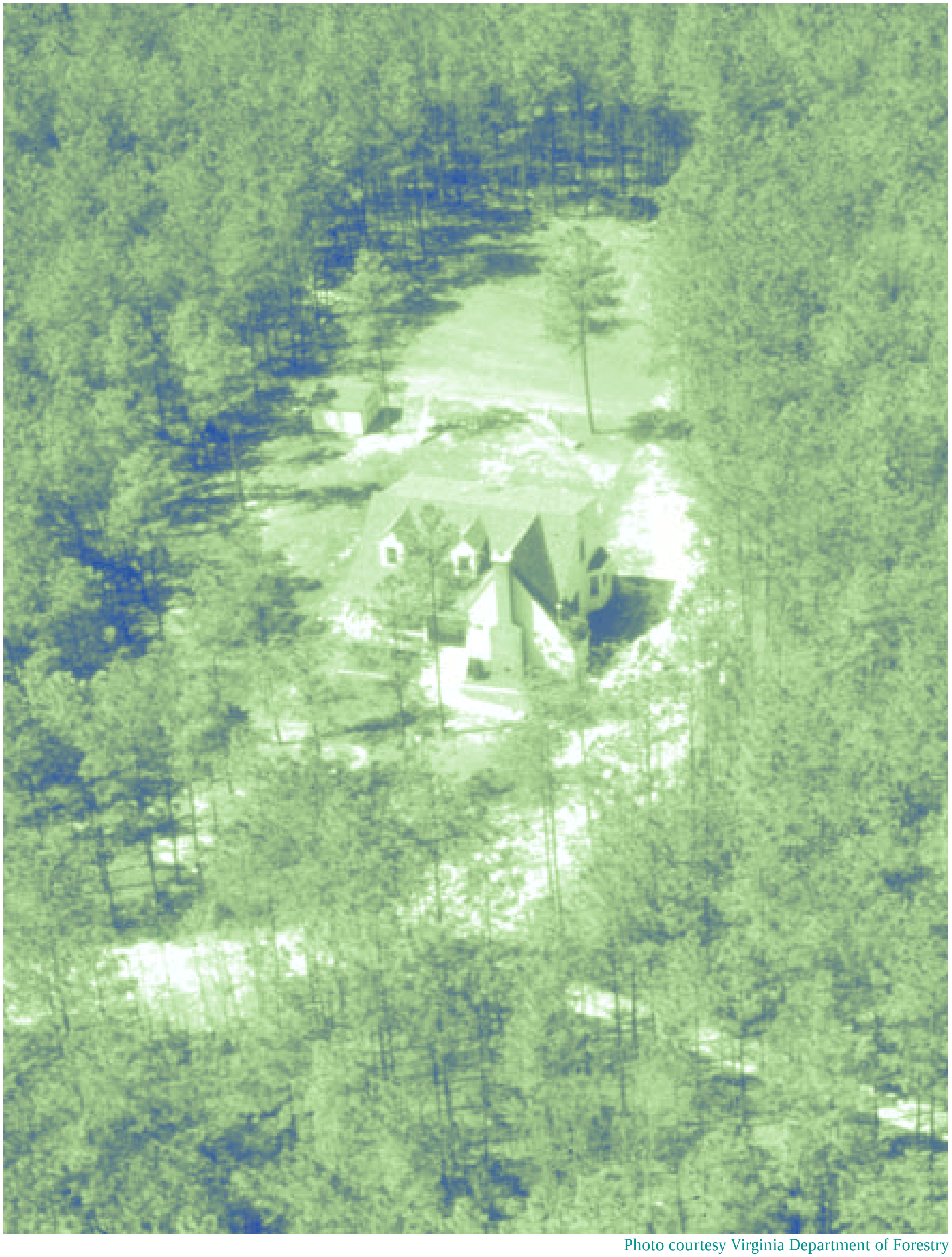

Photo courtesy Virginia Department of Forestry

SOCIAL

How have land uses changed in the South, and how might changes in the future affect the area of forests?

Chapter 6: Land Use

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Key Findings

■ Except for a moderate decline in agricultural uses, most States in the South have experienced relatively stable land use distributions between 1945 and 1992. The most notable exception is Florida, where developed land uses have expanded substantially.

■ Stability in overall land use distributions masks offsetting shifts into and out of forest cover in many States.

■ Urbanization and relative returns to agriculture and timber uses will strongly influence changes in land use during the next 20 years. Urbanization will continue to consume forest land and agricultural land, while rising timber prices will push some agricultural land toward forest uses.

■ The South is forecast to lose 12 million forest acres (8 percent) to developed uses between 1992 and 2020. An additional 19 million forest acres are forecast to be converted to developed uses between 2020 and 2040.

■ Southern forest losses will likely be concentrated in a few places: (1) the Piedmont and Mountain areas of North Carolina, (2) adjacent Piedmont areas of South Carolina and Georgia, (3) Florida, and (4) the Atlantic and gulf coastal areas. Smaller areas with substantial projected losses include areas surrounding the cities of Nashville, TN, and Birmingham, AL, and the area of northern Virginia between Washington, DC, and Richmond, VA.

■ Increased timber prices are forecasted to cause about 10 million acres of agricultural land to be forested between 1992 and 2020. As much as 25 million acres of agricultural land could be forested by the year 2040.

■ Much agricultural land may be converted to forest in some parts of the South. In the eastern part of the South, gains are possible on the upper Coastal Plain of Georgia and on the Coastal Plain in an area centered on the boundary between North Carolina and Virginia. The largest area of potential forest gains is on the lower Gulf Coastal Plain and in large portions of Arkansas, Mississippi, and Louisiana.

■ Taken together, these forecasts suggest a western shift in forest area—losses are concentrated in the eastern South, and gains are concentrated in the western South.

■ Forecasts of a forest population density index indicate that the potential influence of southern urban areas extends far beyond their cores. This condition has important consequences. As the population increases in a forested area, the ability of the forest to moderate microclimate may be reduced. Availability of land for public recreation is normally reduced, and availability for timber management plummets.

■ In some areas, the share of forest cover is relatively high, but forest tracts are highly fragmented. This condition is prevalent in some northern parts of the South, on the Southern Appalachian Piedmont, and in northern Florida. In these areas, marginal changes in the amount of forest cover may have disproportionate impacts on the connectivity of forested habitats.

Introduction

Three major periods characterize land use in the South: (1) the era of agricultural exploitation, (2) the era of timber exploitation, and (3) the era of recovery and renewal. Agricultural exploitation started in the 17th century but reached its zenith in the late 19th century, when a vast cotton industry stretched from the Atlantic to Texas. Other crops supplanted cotton as the boll weevil ran its course, and all have had influence on the land. Timber exploitation, which peaked in the first part of the 20th century, had its roots in the disposal of a large public domain in the years immediately after the Civil War (Williams 1989). The timber industry migrated to the South after timber stocks were depleted in the Lake States, and 20 years of extensive timbering left southern timber stocks similarly depleted. By the start of the Great Depression, intensive agriculture and timbering had seriously degraded the land. Farms were abandoned, and forests were reestablished and renewed over the next 40 years.

Currently, a different set of forces is shaping southern forests. Strong economic growth has fueled increased population and urbanization (Alig and Healy 1987). In addition, relative changes in agricultural and timber markets strongly influence the allocation of rural land to agricultural and forest uses (Alig 1986). Agriculture's returns have generally declined relative to forestry,

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and the South has become the dominant timber-producing region in the country. More than 58 percent of domestic fiber production in 1997 was from the South. Returns to agriculture and forestry vary widely depending on land quality, climate, and location relative to markets. Where agriculture does not dominate and conditions are conducive, much land is actively and intensively managed for timber production. As a result, the South is now the largest agricultural-style timber-producing region in the World.

This chapter describes historic, current, and probable future land use in the South. It identifies the forces that have shaped, and will continue to shape, forest area. It focuses on the relative roles of population change, economic growth, agricultural markets, and timber markets as they interact to define the values of land in different uses. This chapter also examines how increasing populations and development influence the landscape structure of forest landscapes.

Methods

Historical Land Use

Areas in various land uses were obtained from Federal and State agencies. Records of land use before World War II are somewhat spotty, but land use records at the State level have been compiled at irregular intervals since 1945. The most recent of such surveys was conducted in 1992. The U.S. Department of Agriculture Economic Research Service (1996) has constructed a database of areas in major land uses for the period 1945 to 1992 at about 5-year intervals. This database corrects for differences in land use definitions in the various surveys.

We examine shares of each land use by State over this time period. We were also able to examine State-level land use changes between 1982 and 1997 using a different dataset. The 1997 data are the most recent comprehensive measures of land use available.

In addition to these long-run data compiled at the State level, we summarized land use changes for individual counties and for ecological sections between 1982 and 1992. While limited to a shorter period, these data provide a picture of the spatial pattern of land use change.

Land Use Forecasts

To forecast land use change to 2020, we employed a county-level model developed by Hardie and others (2000). This econometric model assumes that:

- The allocation of land between urban and rural uses is driven by population density, personal income, and housing values.
- The allocation of rural land to agricultural and forest uses is driven by returns to local crops, returns to grazing, agriculture costs, land quality, and timber prices. All of these variables except timber prices are defined at the county level of resolution. Timber prices are defined for two or three subregions per State defined by the Timber Mart South price reporting service.

The model was estimated based on land use patterns recorded in 1982, 1987, and 1992 by the National Resource Inventory (NRI) [see Hardie and others (2000) for modeling details]. Detailed land use categories were lumped into four classes: urban/residential, cropland/pasture, forest, and other. The urban/residential class includes areas in transportation and other corridors. The other class can be considered a transitional zone where land use is unclear due to changing conditions.

Before land uses could be projected, we had to forecast the factors that drive changes. Accordingly, we acquired county-level forecasts of population density and personal income and developed forecasts of housing values.

Two core projections were developed to (1) isolate the influence of general economic and population growth on the region and (2) completely assess land use changes that account for market responses to increased scarcity of timber as rural land is developed. The two core projections were defined for the following scenarios:

Urban growth scenario—An initial scenario was developed assuming that the population, income, and housing value forecasts are correct and that the relative positions of timber and agricultural markets do not change in the future. Effects of population growth and economic growth on urban land uses are estimated.

Base scenario—A scenario was also constructed to evaluate how rural land uses might be influenced by a relative shift in returns to agricultural and timber management. This scenario assumes that the population and economic change forecasts in the urban growth scenario hold and that the real price of softwood timber will increase by 35 percent by 2020, consistent with timber market forecasts developed in chapter 13. Agricultural returns are held at their 1992 levels. This scenario was built by imbedding the land use model described here within the timber market model as described in chapter 13. This procedure allowed land use, timber management, timber harvesting, and timber prices to be jointly and consistently determined. [See chapter 13 for a detailed description of modeling assumptions with respect to timber productivity, timber demand, and other factors. See Murray and others (2001) for a description of how these models are linked together.]

A sensitivity analysis was conducted to see how land uses would be affected by different forecasts for timber and agricultural prices. Results show where rural land use may be most sensitive to timber market changes in the South.

The histories of key driving variables were analyzed. Population changes in counties were plotted. Changes in timber and agricultural prices over time were also analyzed.

Forest Conditions

Forest population density—To examine the potential influence of the expanding wildland-urban interface on forests of the region, we construct a simple index. For each county in the South, we divide the number of people by the area of forest in square miles. The resulting forest population density index (FPD) provides a measure of the population pressure on existing and future forests. For example, a high FPD indicates a relative scarcity of forest benefits for people in the county.

Clearly, FPD is a very general measure of human influence, but it helps to define where population effects on forests may be most concentrated and where they may change most in the future. Forecasts of the FPD to 2020 were constructed from population and land use forecasts.

Landscape pattern—Measuring the configuration of forests in a county requires spatially explicit data. The basis of the analysis was a fine-scale (0.09 ha) grid-based map of landcover in each county developed from satellite images of the South. Each 0.9-ha cell is called a pixel.

A forest fragmentation indicator was constructed from the landcover maps as defined by Riitters and others (2000). Landcover was lumped into forest and nonforest classes, and the index was calculated based on the amount and connectivity of forest pixels within a fixed area around each pixel. The "forest" class included shrubland, woody wetland, and three upland forest types on the landcover maps. A value representing the forest fragmentation indicator was assigned to the center pixel. The pixel value thus describes the forest fragmentation condition within which that pixel of landcover occurs. Forest fragmentation values were constructed for two different neighborhood sizes: 7 ha (17 acres) and 66 ha (163 acres). Six forest fragmentation classes were defined:

1. Perforated—Most of the pixels in the surrounding area are forested, and this pixel appears to be part of an inside edge of a forest patch. In other words, this pixel is near a nonforest inclusion within a forest.

2. Edge—Most of the cells in the surrounding area are forested, and this cell appears to be part of the outside edge of a forest patch.

3. Transitional—About half of the pixels in the surrounding area are forested, and this pixel may appear to be part of a patch, edge, or perforation depending on the local forest pattern.

4. Patch—Most of the pixels in the surrounding area are not forested, and this pixel is part of a forest inclusion or patch of forest on a nonforest background.

5. Interior—All of the pixels in the surrounding area are labeled as forest in the landcover map.

6. Nonforest—Essentially none (less than 0.5 percent) of the pixels in the surrounding area are labeled as forest in the landcover map.

Cells labeled water or with missing values were excluded, and data were summarized for counties and ecological sections. Fragmentation was summarized in two ways: (1) the share of area that is interior forest as defined above and (2) the share of edge-dominated forest, defined by summing the shares of area in edge, transitional, and patch categories. This scheme leaves out the perforated category, which may indicate an intensively managed forest area, but is neither interior forest nor clearly edge-dominated.

Data Sources

Historical Land Use

Land use databases: major land uses database—This database contains land uses by major category for each Census of Agriculture year (roughly every 5 years) between 1945 and 1992. The database was constructed by the U.S. Department of Agriculture Economic Research Service. To document general trends in land use for the South, we report data for the 11 entire Southern States within the region. Texas and Oklahoma are excluded because only small portions of these States are in the Assessment area, and the portions not included have very different ecological conditions. Including totals for Texas and Oklahoma therefore would significantly skew the results.

We report land uses by the following categories:

1. Cropland—This category includes cropland harvested, crop failure, cultivated summer fallow, cropland used only for pasture, and idle cropland.

2. Pasture—This category includes all open land used primarily for pasture and grazing. Forested pasture is included under forest land.

3. Forest land—This category is generally consistent with U.S. Department of Agriculture Forest Service definitions of forest. It includes land at least 10-percent stocked by trees of any size and land formerly having had such tree cover that will be naturally or artificially regenerated. These data are not necessarily consistent with Forest Service estimates of forest land area due to differences in classification of dominant land use. In spite of these differences, estimates provide a useful means for examining regional trends in forest area consistent with changes in other land use categories.

4. Urban plus rural transportation—Urban areas are incorporated and unincorporated places of 2,500 or more people. Rural transportation corridors include highways, roads, and railroad rights-of-way, plus airport facilities.

5. All other—The difference between categories 1 through 4 and total land area.

Land use databases: National Resource Inventory—The NRI is a multiresource inventory conducted on non-Federal lands by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS). The NRI was conducted in 1982, 1987, 1992, and 1997. The inventory uses a statistically based sample of plots with information compiled on landcover or use, wetlands, habitat diversity, etc. We report land use data aggregated to the county and the ecological section levels.

Definitions of land use categories are somewhat different from those used in the Land use databases: major land uses database described earlier. We report NRI land uses by the following four categories:

1. Agriculture: cultivated and uncultivated cropland plus pasture.

2. Forest land: area that is "at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters tall (13 feet) at maturity. Also included is land bearing evidence of natural regeneration of tree cover and not currently developed for nonforest use" (National Cartography and Geospatial Center 1998).

3. Urban and built-up areas. "A landcover category consisting of residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards;" etc., as well as tracts of less than 10 acres that "are completely surrounded by urban and built-up land" (National Cartography and Geospatial Center 1998).

4. Other: Defined here as total non-Federal land minus the area in categories 1 through 3.

Driving variables: population and personal income—Historical data were taken from the U.S. Census and arrayed at the county level. Forecasts of population and personal income were the baseline projections developed for the U.S. Assessment of Possible Vulnerabilities to Climate Variability and Change (NPA Data Services, Inc. 1999).

Driving variables: agricultural land rents—Statewide annual land rent data for the period 1960 to 1994 were taken from a database compiled by the U.S. Department of Agriculture Economic Research Service. Farmland rent is defined as the difference between revenues and total variable costs for both crop and pasture uses. The rents per acre per farm were adjusted for inflation by the gross domestic product price deflator.

Driving variables: timber prices—Rents for forest management directly comparable to the agricultural rents described above are not available in the South. To index the relative returns to forest uses, we examined real stumpage prices for sawtimber and pulpwood from Louisiana for the period 1960 to 1996. These are the only consistently measured stumpage prices available in the South for this extended period. The source of the data is Louisiana severance tax records reported by Ulrich (1987) for 1950 to 1965 and by Howard (1999) for 1966 to 1996.

Table 6.1—Allocation of southern land among major uses, 1945-92[a]

Year	Cropland	Forest	Pasture	Urban[b]	Other
			Percent		
1945	25.1	54.6	8.0	2.1	10.1
1949	26.7	55.9	6.0	2.5	8.9
1954	24.2	57.6	8.1	2.6	7.5
1959	21.6	58.1	10.3	3.2	6.7
1964	20.5	60.0	9.6	3.6	6.3
1969	23.1	58.1	8.2	3.8	6.8
1974	23.1	57.9	7.9	4.3	6.9
1978	23.7	57.0	6.2	5.3	7.8
1982	22.9	55.7	7.3	5.8	8.3
1987	21.7	55.4	7.2	6.6	9.1
1992	21.5	56.2	6.7	6.6	9.0

[a] Values for Texas and Oklahoma are not included.
[b] Urban includes transportation corridors.

Units are dollars per thousand board foot Scribner for sawtimber and dollars per cord for pulpwood.

Forest Area Conditions

Landscape patterns: Multi-Resolution Land Characteristics (MRLC) landcover maps—The MRLC consortium (Loveland and Shaw 1996) has developed landcover maps with a consistent interpretation protocol for the entire South. The MRLC protocol (Vogelmann and others 1998) combines Thematic Mapper (satellite) imagery from the early 1990s with other spatial databases to map landcover at a spatial resolution of 0.09 hectares per pixel. Thirteen State maps were obtained from the MRLC database and combined for this analysis. The maps for three of the States (Arkansas, Oklahoma, and Texas) were in draft form at the time of this analysis (December 2000). The parts of Oklahoma and Texas outside the Assessment area were excluded from the analysis. The landcover maps were summarized for the original 21 landcover types and also for a lumped 8-class version of the map. Lumped categories are: (1) water, (2) developed/urban, (3) barren/disturbed, (4) forest, (5) shrubland, (6) agriculture, and (7) grassland.

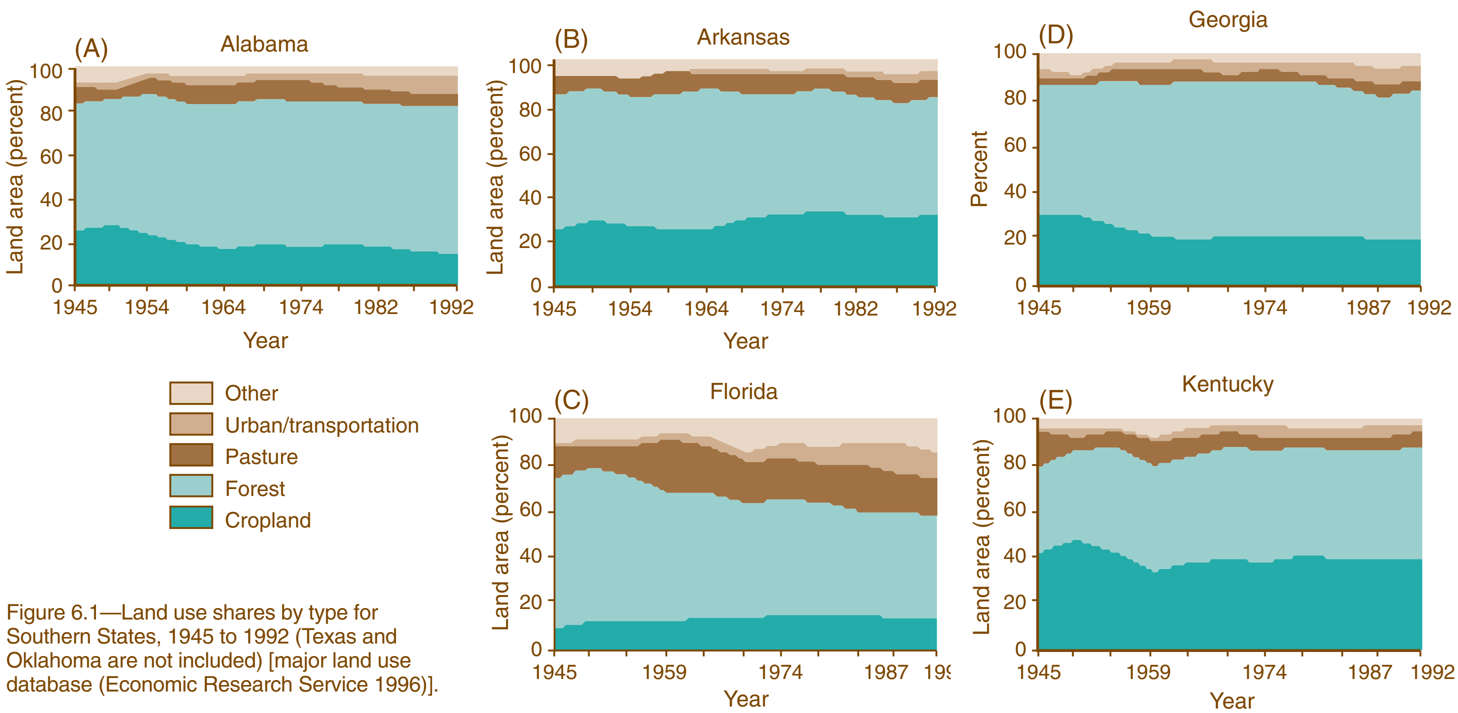


Figure 6.1—Land use shares by type for Southern States, 1945 to 1992 (Texas and Oklahoma are not included) [major land use database (Economic Research Service 1996)].

Results

Historical Land Use

State-level land use changes— Between 1945 and 1992, two major changes in land use occurred: (1) the area of urban and rural transportation uses roughly tripled, from 2.1 to 6.6 percent of land area, and (2) agricultural uses declined. This finding is consistent with population growth observed over the same period. Total agricultural uses (cropland plus pasture) declined from about 33 percent in 1945 to about 28 percent in 1992 (table 6.1). In contrast, forest area has been roughly constant. It was about 56 percent of the South in 1992 and ranged from a low of 55 percent in 1945 to a high of 60 percent in 1964.

Trends varied considerably among States (fig. 6.1). In Florida, area of forest declined from 66 percent of the land area in 1945 to 45 percent in 1992. Between 1945 and 1974, the area of land in agriculture increased steadily. Since 1974, growth in urban uses and rural transportation uses has dominated. In 1945, 3 percent of Florida was in human-dominated use; by 1992, that area had risen to 12 percent.

Georgia, Alabama, Tennessee, Kentucky, and the Carolinas all experienced declines in agricultural land uses from 1945 to 1964, with compensating gains in forest land. Other States had relatively stable agricultural area over this period. In all States, forest is the dominant land use, but the degree of dominance has changed in many States (fig. 6.1).

The pattern of change for forest land also differs among States. With the exceptions of Arkansas, Florida, and Louisiana, all States had more forest land in 1992 than they did in 1945. In the eight States with gains, land use shifted strongly from agriculture to forest between 1945 and 1969. Georgia, North Carolina, and Virginia have experienced declines in forest area since the early seventies. Over the same period, area in forest has been essentially stable in Alabama, Kentucky, Mississippi, South Carolina, and Tennessee.

Data from the NRI provide the most recent measures of land use change in the United States. The predominant pattern of change between 1982 and 1997 has been an erosion of the total area of cropland and an increase in the area of developed uses. The total area of pasture and forest declined only slightly between 1982 and 1997 (fig. 6.2). Most of the urban land uses and

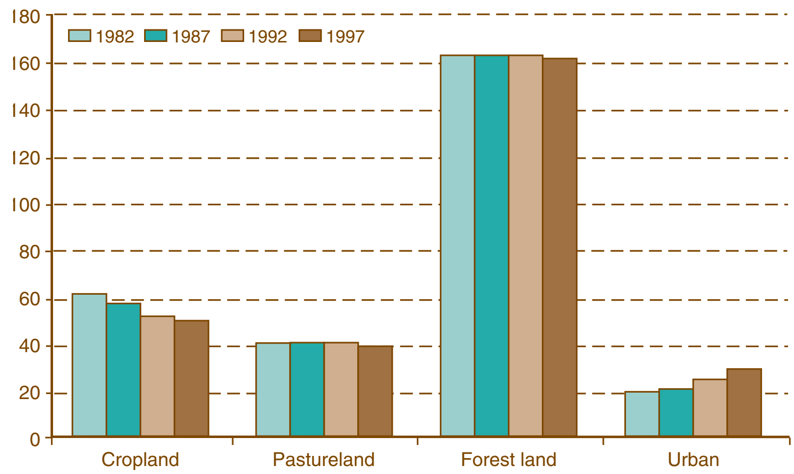
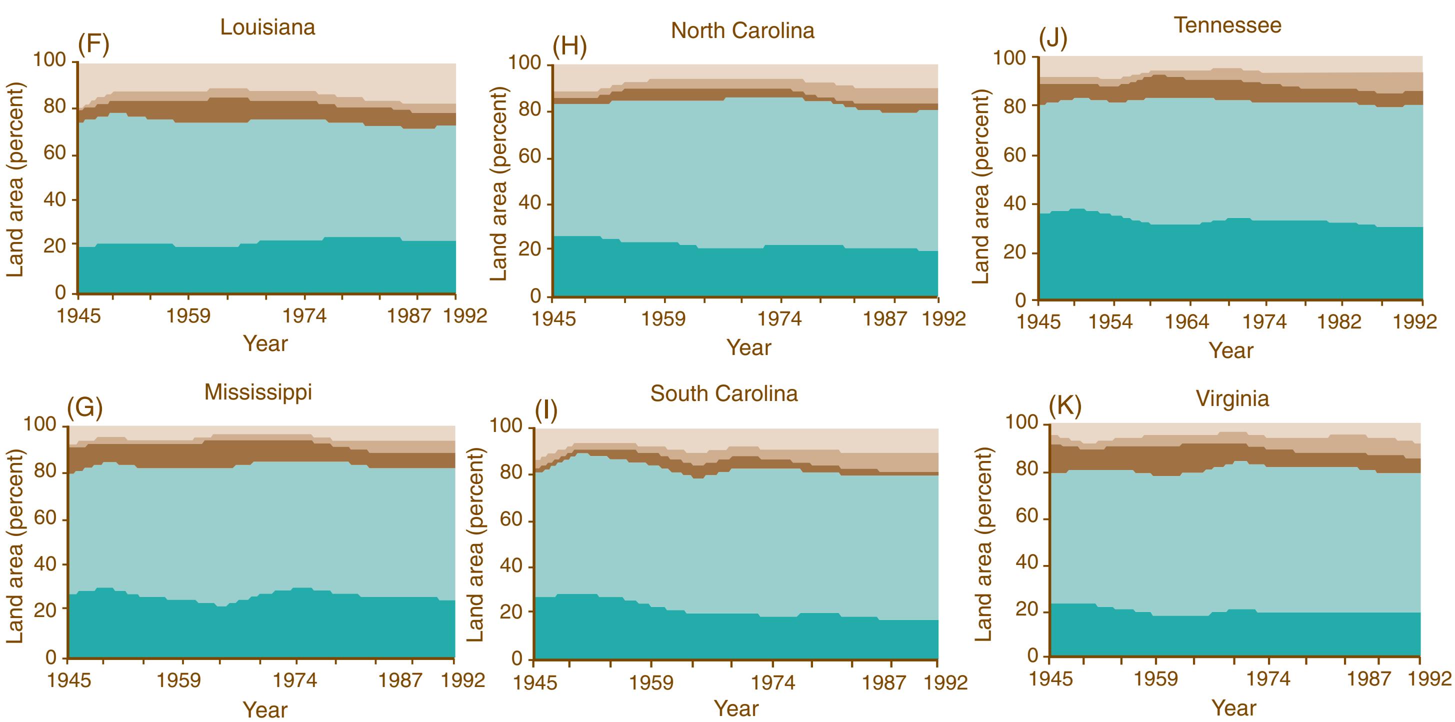


Figure 6.2—Area of land in crop, pasture, forest, and urban land uses for Southern States 1982 to 1997 (Texas and Oklahoma are not included in totals) [National Resource Inventories (National Cartography and Geospatial Center 1998)].



the observed increase in urban land uses was concentrated in the five States along the Atlantic Coast from Virginia to Florida. These States all had more than 7 percent of their non-Federal land in urban uses (fig. 6.3). These States plus Tennessee had the highest growth in the percent of land in urban uses from 1982 to 1997. In these States, 3 to 6 percent of non-Federal land was developed over this period.

The preceding data describes net change in land use. There can be considerable offsetting changes between land uses that are not revealed by measures of net change. While we could not derive gross changes at the State level from the available NRI data, the 1997 NRI report indicates that 9.6 percent of all rural non-Federal land in the United States experienced a land use change between 1982 and 1997. That number is likely to be higher in the East, where the share of private lands is much higher than in other regions. Land use data from forest inventories described in chapter 16

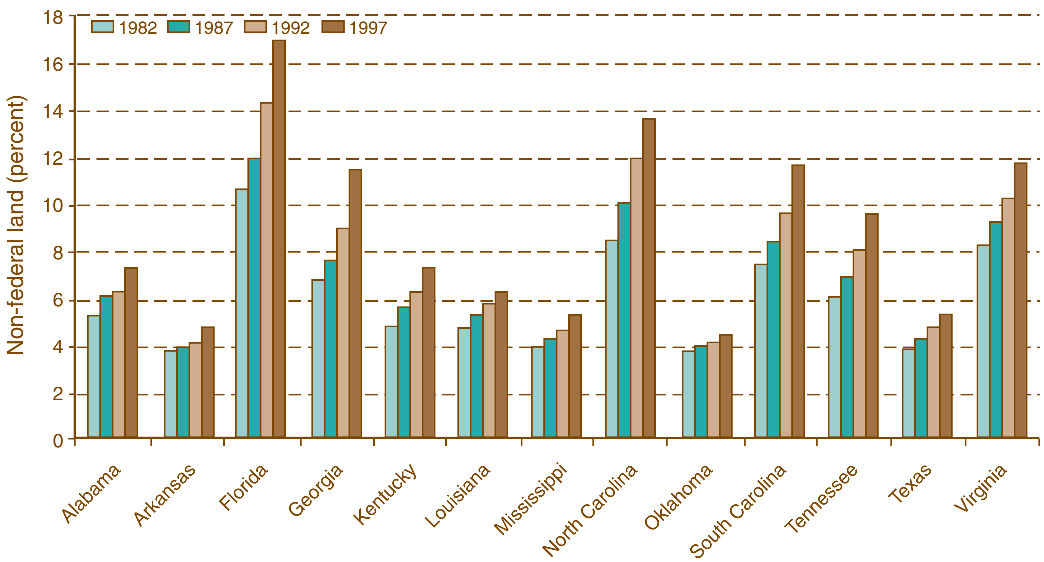


Figure 6.3—Percent of land in urban uses for Southern States 1982 to 1997 [National Resource Inventories (National Cartography and Geospatial Center 1998)].

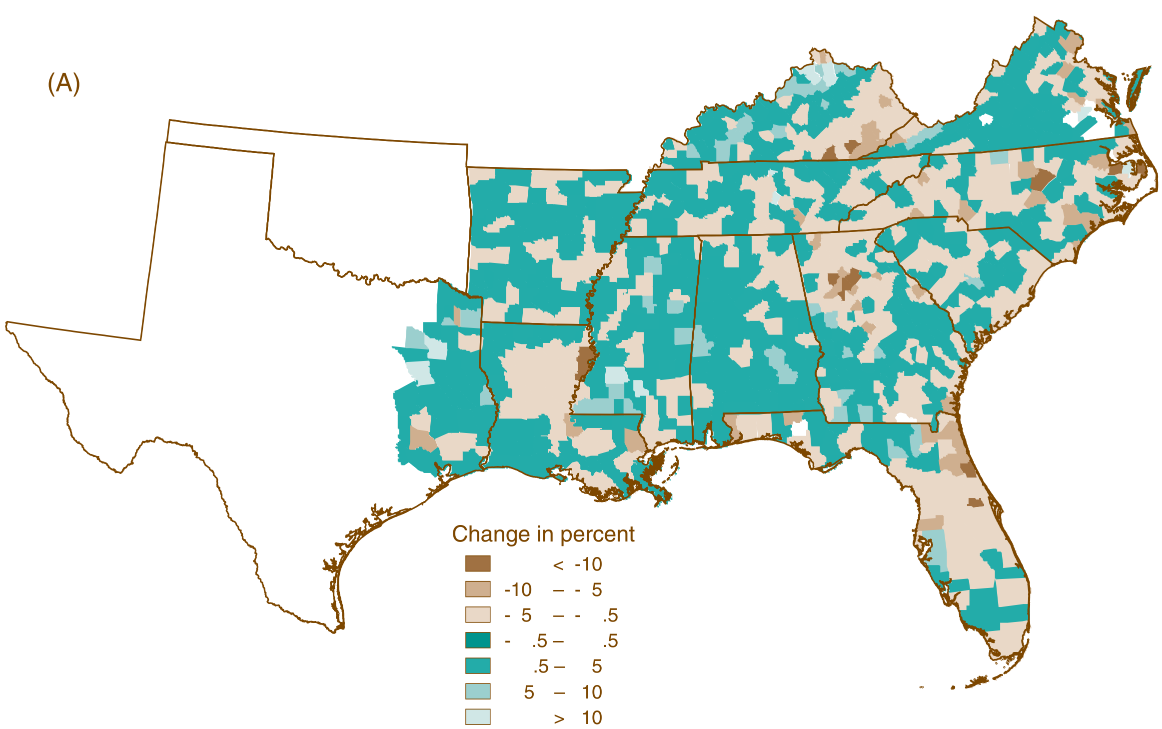


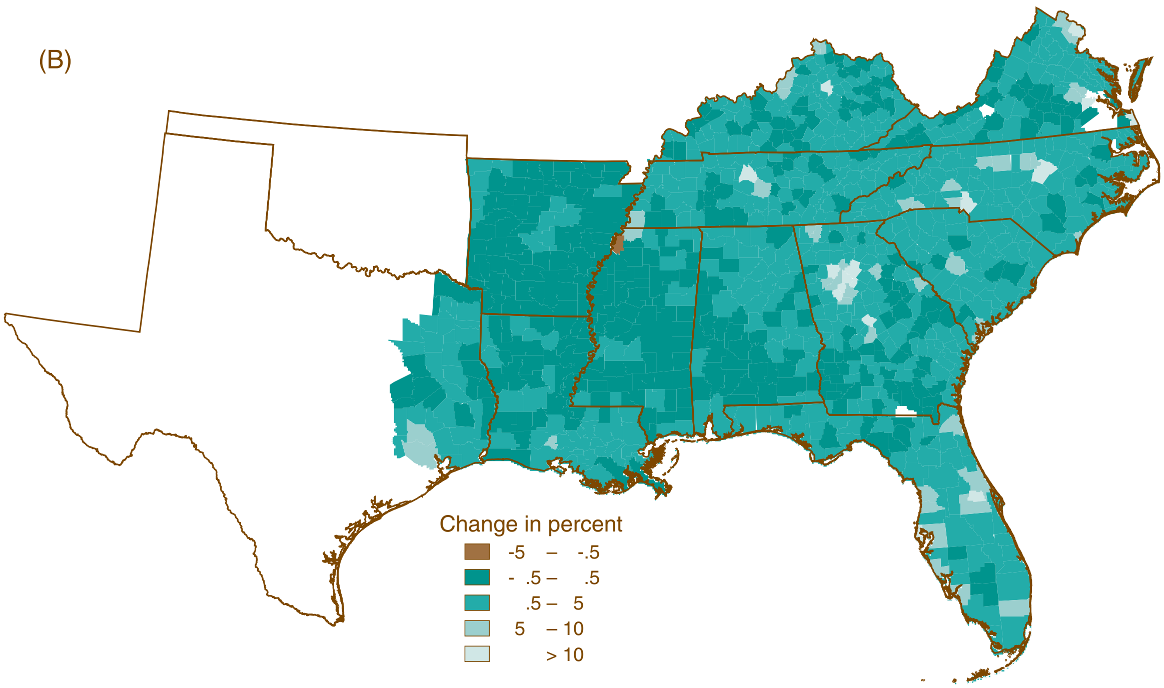
Figure 6.4—Changes in percent of (A) forest, (B) urban, and (C) agricultural land uses by county for 1982 to 1992 [National Resource Inventories (National Cartography and Geospatial Center 1998)].

reveal that over the past 20 years 2 to 3 million acres per year experience a change either from forest to nonforest or vice versa. These changes imply a significant impact on the condition of forests and their ability to provide wildlife habitat (see chapter 3), recreation (chapter 11), and environmental amenities (chapter 12).

County-level land use changes— County-level data show that major changes in land use occurred between 1982 and 1992 even though many Statewide totals were essentially unchanged (fig. 6.4). Forest area in southern and central Alabama and Mississippi rose at the expense of agricultural uses (figs. 6.4A and 6.4C). Similar shifts toward forest occurred in the upper Coastal Plain of South Carolina and Georgia, in northern and western Kentucky, and in western Tennessee.

Loss of forest land was generally concentrated in areas of rapid population growth and urbanization. Population growth was most substantial around Atlanta, GA, Washington, DC, Richmond, VA, Raleigh and Charlotte, NC, Nashville, TN, Charleston, SC,

(B)



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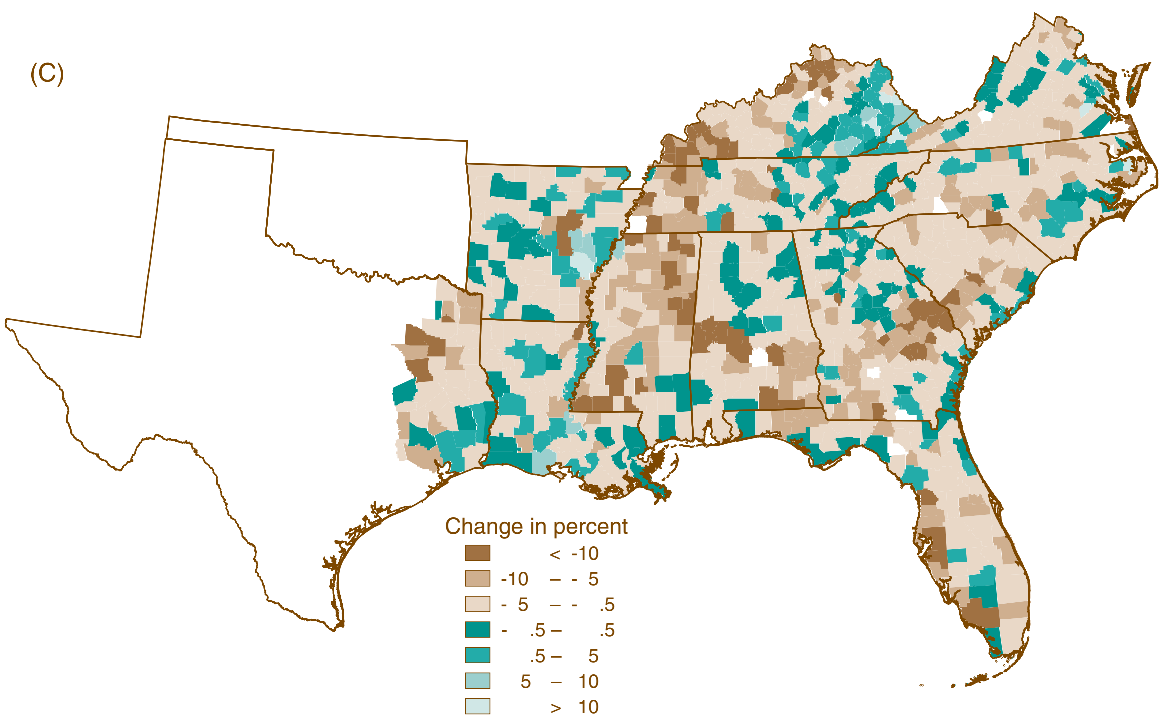

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and the coastal cities of Florida. Some forest loss was also associated with expanding agricultural uses in east-central Arkansas and in parts of Kentucky, Louisiana, and North Carolina.

These county-level changes were aggregated to measure change by ecological section of the South. Forest loss was concentrated in the eastern part of the region (fig. 6.5) (table 6.2). The Florida Coastal Lowlands and the Atlantic Coastal Flatlands—essentially the Atlantic Coast of the South—had the highest percentage losses of forest land (3.7- and 2.6-percent loss, respectively). The Southern Unglaciated Allegheny Plateau, the Northern Cumberland Plateau, and the Southern Ridge and Valley also experienced relatively high losses. Another large contiguous block that includes the Northern Cumberland Mountains, the Mid-Atlantic Coastal Plain, the Blue Ridge Mountains, and the Southern Appalachian Piedmont lost more than 600,000 acres of forest.

Table 6.2—Change in the percent of area in forest and amount of forest area by ecological section, 1982-92[a]

Ecological section	Change	
	Acres	*Percent*
Florida Coastal Lowlands (Eastern)	-183,100	-3.72
Atlantic Coastal Flatlands	-362,156	-2.58
Southern Unglaciated Allegheny Plateau	-36,900	-2.13
Northern Cumberland Plateau	-178,900	-2.09
Southern Ridge and Valley	-72,500	-1.74
Northern Cumberland Mountains	-23,200	-1.45
Middle Atlantic Coastal Plain	-83,900	-1.27
Blue Ridge Mountains	-152,500	-1.16
Southern Appalachian Piedmont	-492,500	-1.12
Mississippi Alluvial Basin	-220,800	-0.91
Central Ridge and Valley	-29,500	-0.90
Southern Cumberland Mountains	-19,800	-0.83
Ouachita Mountains	-29,600	-0.82
Everglades	-34,026	-0.65
Coastal Plains and Flatwoods, Western Gulf	-29,600	-0.41
Arkansas Valley	-9,500	-0.25
Boston Mountains	-7,400	-0.21
Louisiana Coast Prairies and Marshes	-11,400	-0.15
Coastal Plains and Flatwoods, Lower	-81,900	-0.15
Ozark Highlands	-7,500	-0.14
Florida Coastal Lowlands (Western)	6,900	0.12
Southern Cumberland Plateau	6,900	0.13
Upper Gulf Coastal Plain	16,800	0.24
Interior Low Plateau, Highland Rim	68,200	0.40
Northern Ridge and Valley	30,900	0.41
Central Gulf Prairies and Marshes	5,100	0.46
Mid Coastal Plains, Western	274,900	1.16
Eastern Gulf Prairies and Marshes	18,300	1.90
Coastal Plains, Middle	795,600	2.13
Interior Low Plateau, Shawnee Hills	128,900	2.66
Interior Low Plateau, Bluegrass	224,600	3.69
Oak Woods and Prairies	197,200	3.97
Total	-292,382	

[a] Entries are sorted by change in percent from largest loss to largest gain. Data were developed by aggregating county-level observations for forest land use from the National Resource Inventory into their respective ecological sections as defined by Rudis (1999).

Forest gains between 1982 and 1992 were concentrated mainly in the western half of the South, especially the middle Coastal Plain of Alabama and Mississippi. On the western side of the Mississippi River, gains were recorded in the Interior Lowland Plateau, the oak woods and prairies, and the eastern gulf prairies and marshes.

Driving variables: agricultural land rent—Changes in the relative values of agricultural and forest land uses can cause shifts from one use to another (Alig 1986). To measure change in agricultural returns, we examined farm rents for the period 1960 to 1994. Figure 6.6 shows rents for five States in the South that are typical of patterns for all others in the region. It shows that real agricultural rents declined in the South in the 1980s but does not show the variation that occurs within a State where specific rents depend on local site factors.

Driving variables: timber prices—Timber prices have also changed substantially over the last 30 years. Figure 6.7 shows that both pulpwood and sawtimber prices increased rapidly between 1970 and 1980, declined in the early 1990s, and then rose again through the late 1990s. Between 1986 and 1996 the real price of pulpwood increased by about 50 percent, while the real price of softwood sawtimber more than doubled. These changes translated into rising timber rents. As a result, we can infer that the agriculture-to-forestry rent ratio has fallen markedly from the mid-1980s on.

Driving variables: population—A critical determinant of the amount of forest in a county is its population density. Population of the South has grown steadily between 1940 and 2000 (fig. 6.8). Since 1980, the region's growth has outpaced the growth in the U.S. population as a whole, indicating an increase in the share of the Nation's population living in the South. Between 1970 and 2000, the share of the U.S. population in the 13 States of the Assessment area grew from 27 to 33 percent.

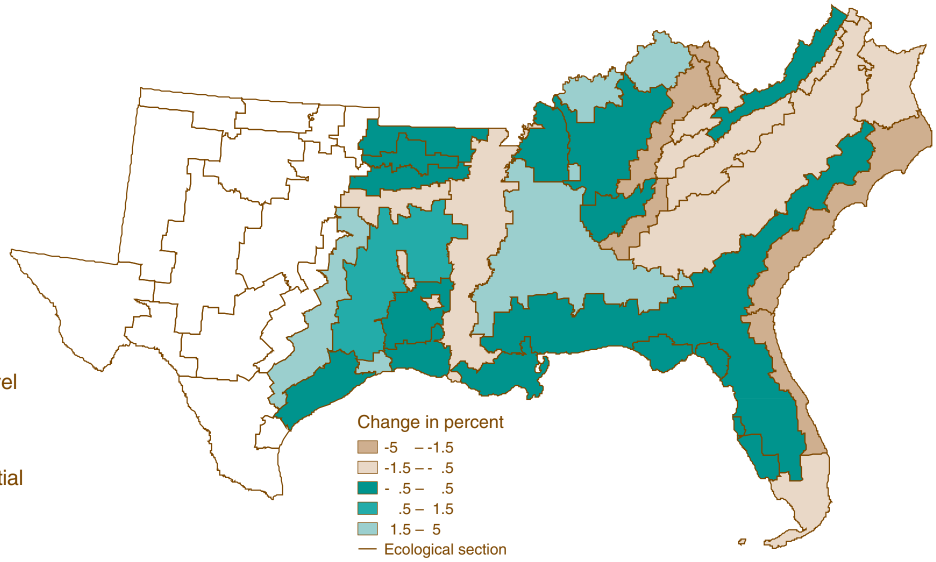


Figure 6.5—Summary of county-level changes in percent forest area by ecological section in the South [National Resource Inventories (National Cartography and Geospatial Center 1998), county aggregation according to Rudis (1999)].

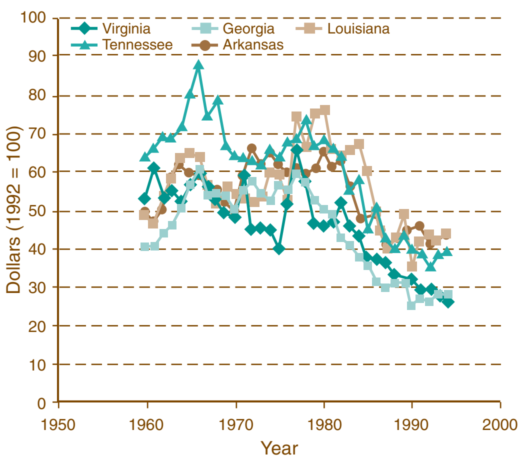


Figure 6.6—Agricultural rents for 1960 through 1994 for Virginia, Tennessee, Georgia, Arkansas, and Louisiana [rents are adjusted for inflation by the gross domestic product price deflator (1992 = 100)] (Jones 1997)].

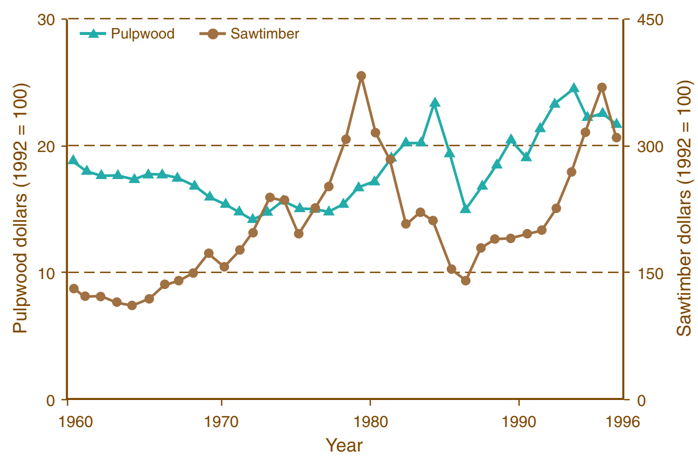


Figure 6.7—Real prices paid for softwood pulpwood and sawtimber in Louisiana, 1960 to 1996. Prices are adjusted for inflation by the gross domestic product price deflator (1992 = 100) [Louisiana severance tax records as reported in Ulrich (1987) and Howard (1999)].

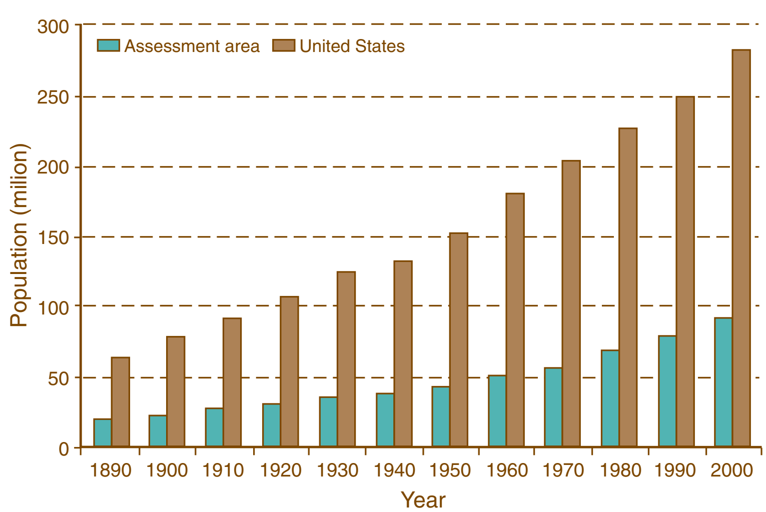
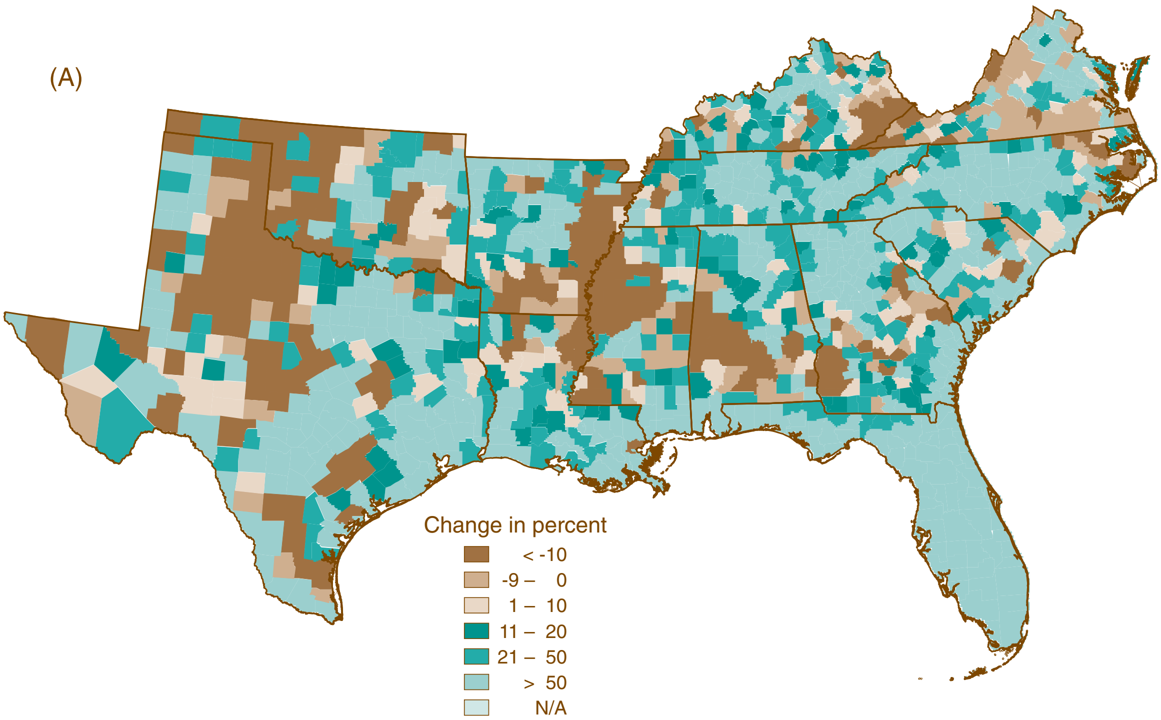


Figure 6.8—Population for the United States and for the 13 States in the Assessment area from 1890 to 2000 (U.S. Census Bureau 2002).

Growth in population has not been uniform across space or across time. Population growth between 1950 and 2000 was concentrated in the Southern Appalachian Piedmont and along both the Atlantic and gulf coasts (fig. 6.9A). Population density declined in rural portions of the Coastal Plain in Alabama, Mississippi, Arkansas, and Georgia. While population generally declined in rural areas and increased in urban areas in the 1960s (fig. 6.9B), by the 1990s nearly every county in the South was experiencing some population growth (fig. 6.9C).

(A)



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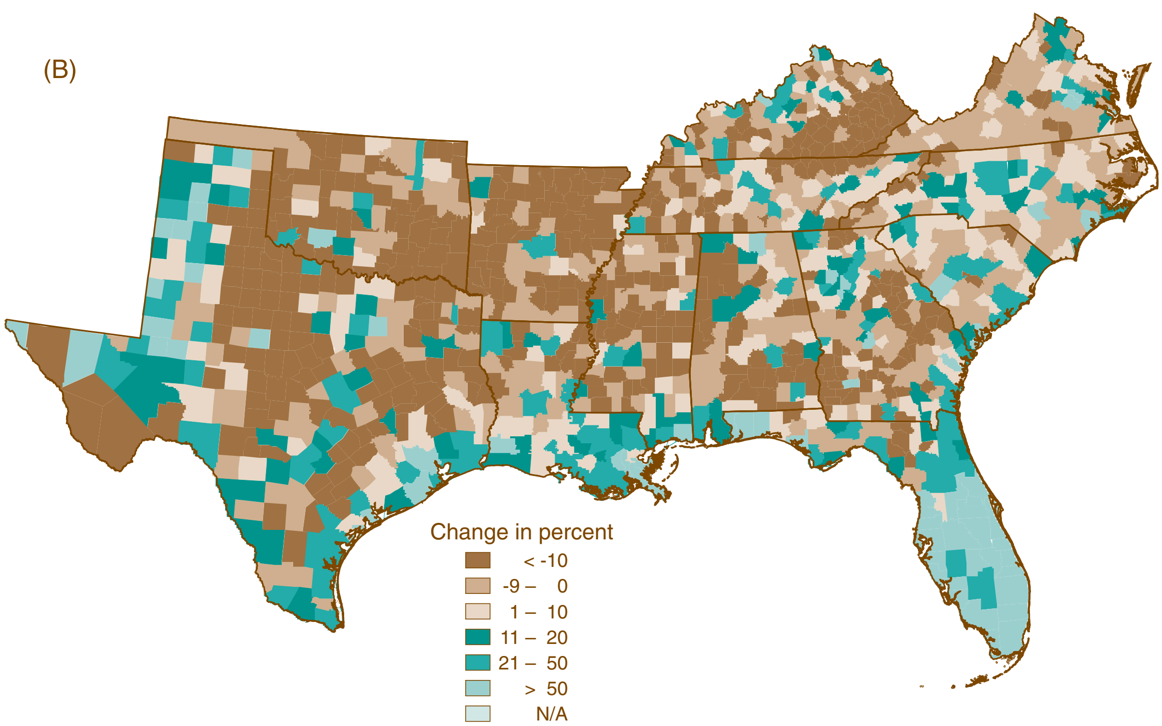


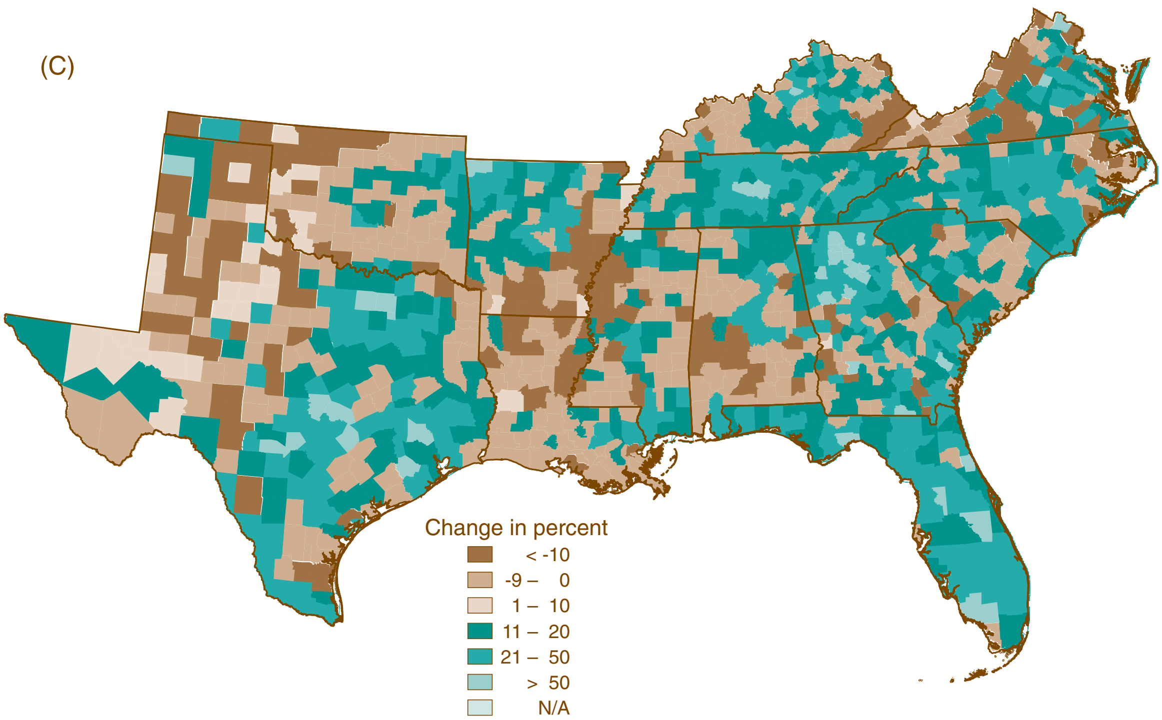
Figure 6.9—Percent changes in the density of population for (A) 1950 to 1999, (B) 1950 to 1960, and (C) 1990 to 1999 (U.S. Census Bureau 2002).

Land Use Forecasts

Urban growth scenario—The urban growth scenario evaluates potential changes in land use driven by anticipated changes in population, personal income, and housing values in the South. Relative returns from agricultural and forestry uses are held constant at their 1992 values. The focus, therefore, is on changes in the factors that influence the distribution of land between urban and rural uses. Forecasts were made for 2020 and 2040 and examined in detail for 2020.

The urban growth scenario indicates a growth in urban area from about 20 million acres in 1992 to 55 million acres in 2020 and to 81 million acres in 2040 (fig. 6.10). Without price adjustments in rural land markets (addressed later), land would shift out of agricultural, forest, and other uses. Forest area declines by about 12 million acres, agriculture by about 13 million acres, and other by about 7 million acres.

(C)



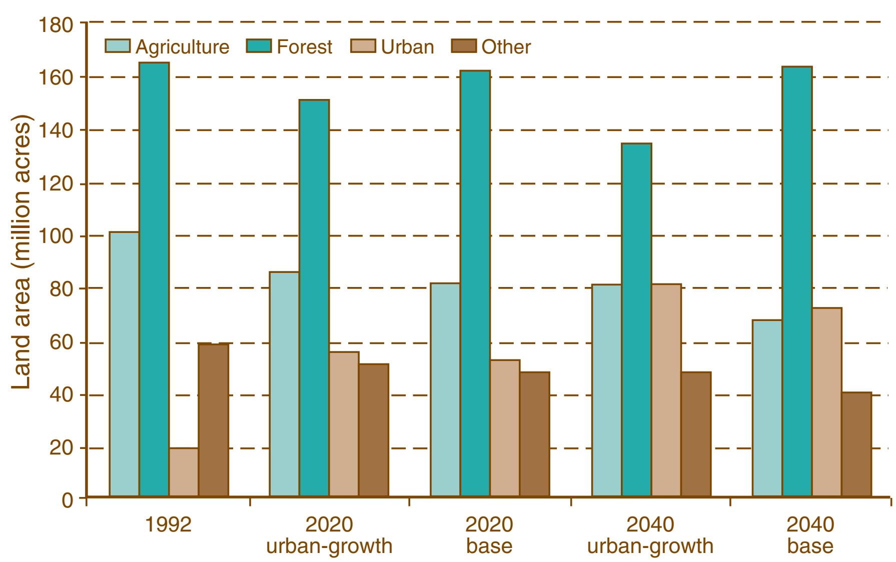


Figure 6.10—Areas of land in agriculture, forest, urban and other in 1992 and for four forecast scenarios [land use forecasting model described in Hardie and others (2000)].

In the forecast for 2020, substantial population and income growth are projected for about one-third of the region's counties. Urbanization is concentrated in three large areas (fig. 6.11): (1) the Southern Appalachian Piedmont stretching from Raleigh/Durham, NC, through Atlanta, GA; (2) the Atlantic Coast from the Carolinas through Florida; and (3) a portion of the gulf coast centered on Mobile Bay. Other centers of expanding urbanization are around Nashville and Knoxville, TN, and in northern and eastern Virginia.

Urbanization dominates rural land use, reducing the areas of both agricultural and forestry uses. Especially large losses of agricultural land are anticipated in Florida, central Tennessee, and central North Carolina (fig. 6.11B).

Losses of forest land are concentrated in areas of expected urbanization (fig. 6.11C). The Southern Appalachian Piedmont of the Carolinas and Georgia, central Tennessee, and Florida all are expected to experience substantial losses of forest land in response to population and income change.

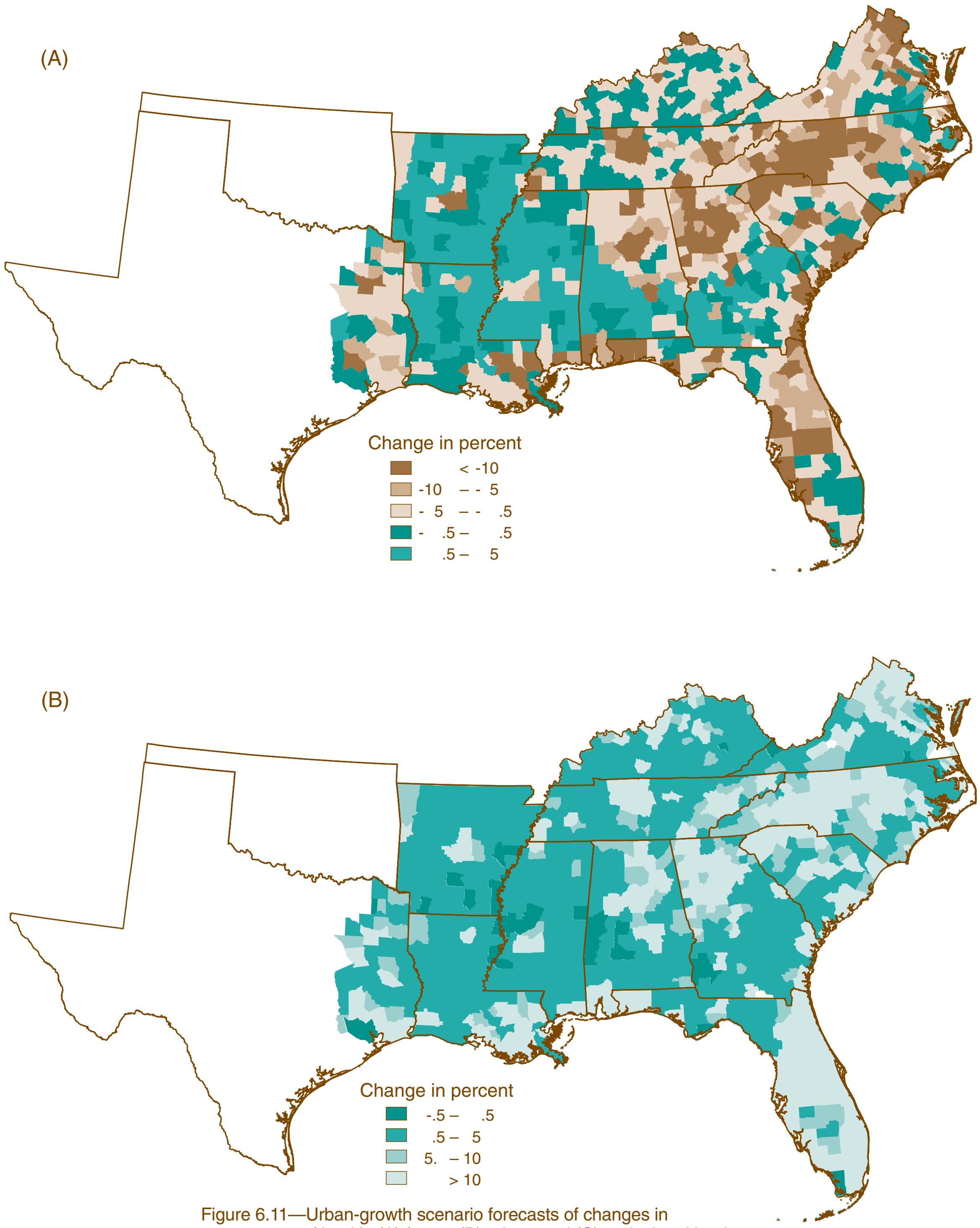
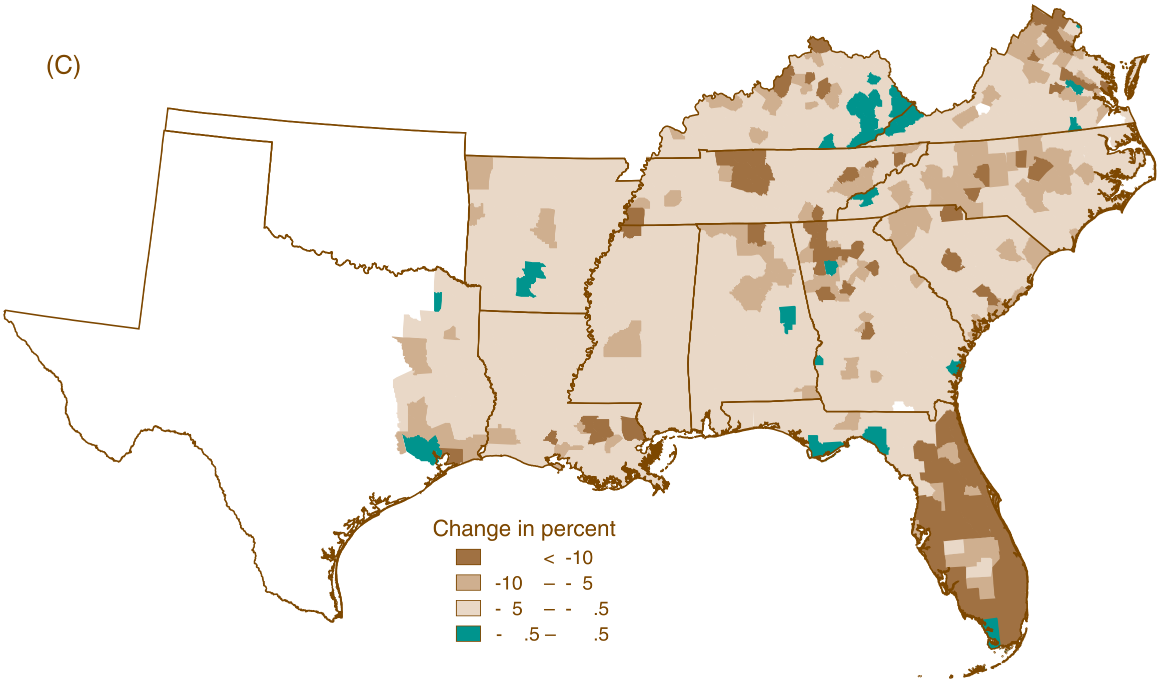


Figure 6.11—Urban-growth scenario forecasts of changes in percentages of land in (A) forest, (B) urban, and (C) agricultural land uses by county for 1992-2020 [land use forecasting model described in Hardie and others (2000)].

(C)



Mapping changes in land use by ecological section shows that forest loss will generally be concentrated in the eastern half of the South. The ecological section with the greatest loss will be the Southern Appalachian Piedmont. Figure 6.12 again shows forest losses would be high along the entire Atlantic Coast and the gulf coast of Florida. The largest contiguous block of forest loss will include the Southern Appalachian Piedmont, the Blue Ridge Mountains, the Ridge and Valley, and the Southern Cumberland Plateau.

Base scenario—The base scenario shows how the urban growth scenario would be altered if timber rents continued to increase relative to agricultural rents consistent with the timber base modeling in chapter 13. A 35-percent increase in real forest rent relative to real agricultural rent is forecast for 2020; a 75-percent increase is forecast for 2040.

The expected increase in timber prices has two effects shown by comparing the urban growth and base scenarios. One is to dampen slightly the demand for land in urban uses. As a result, urban land is forecast to be at about

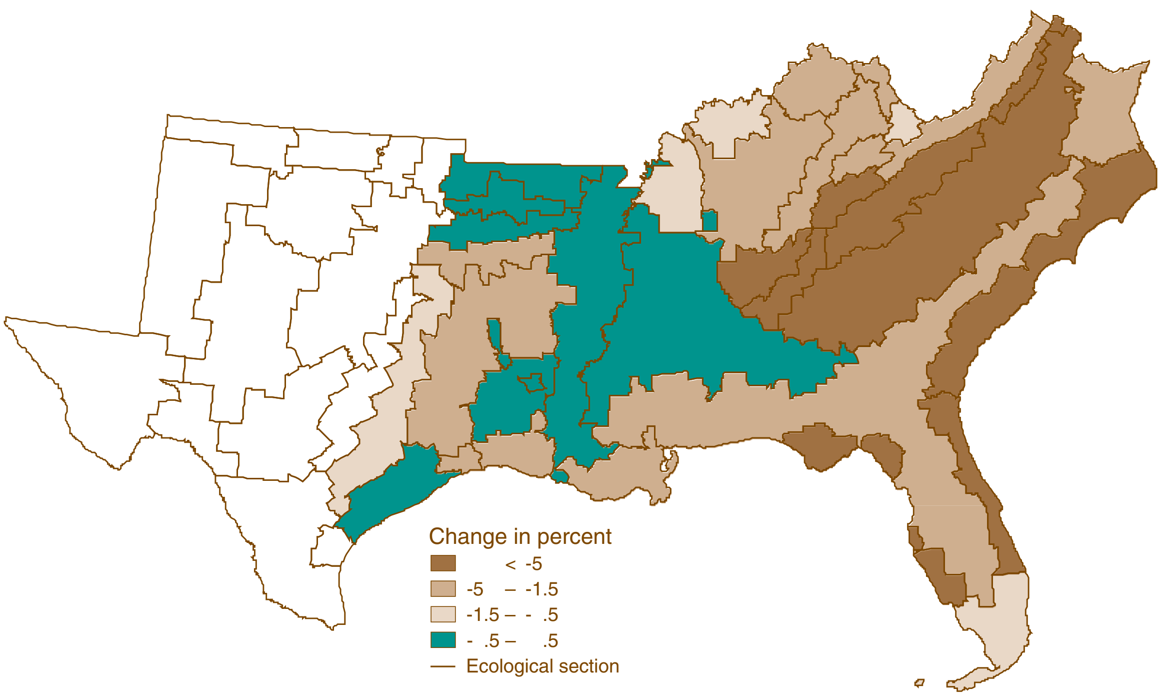


Figure 6.12—Forecast changes in percent of forest by ecological section for 1992 to 2020 under the urban-growth scenario [land use forecasting model described in Hardie and others (2000), county aggregation according to Rudis (2000)].

52 million acres rather than 55 million acres in 2020 and at 72 million acres rather than 81 million acres in 2040. The other effect is that some agricultural land would be planted to forest cover. Roughly 8 million acres would be planted by 2020 and 23 million acres by 2040 (fig. 6.10). The estimate of planting area is the difference between the areas of agricultural land use for the urban growth and base scenarios. The net effects are: (1) urban area expands, (2) forest change is nil, and (3) agricultural and other land declines. Consistent with history, gross changes among land uses would continue to be substantial.

The increase in timber prices leads to shifts from agriculture to forest in the South in 2020. Certain areas of the South may be especially sensitive to these changes (fig. 6.13). In the eastern half of the region, two areas show an increase in forest area. One is a small area in the upper Coastal Plain centered on the border between North Carolina and Virginia. The other is the entire upper Coastal Plain of Georgia and parts of the Coastal Plain of South Carolina. These findings are consistent with a recent study by Ahn and others (2001), who also found the potential for gains in forest land in spite of urban pressures in the western half of the South.

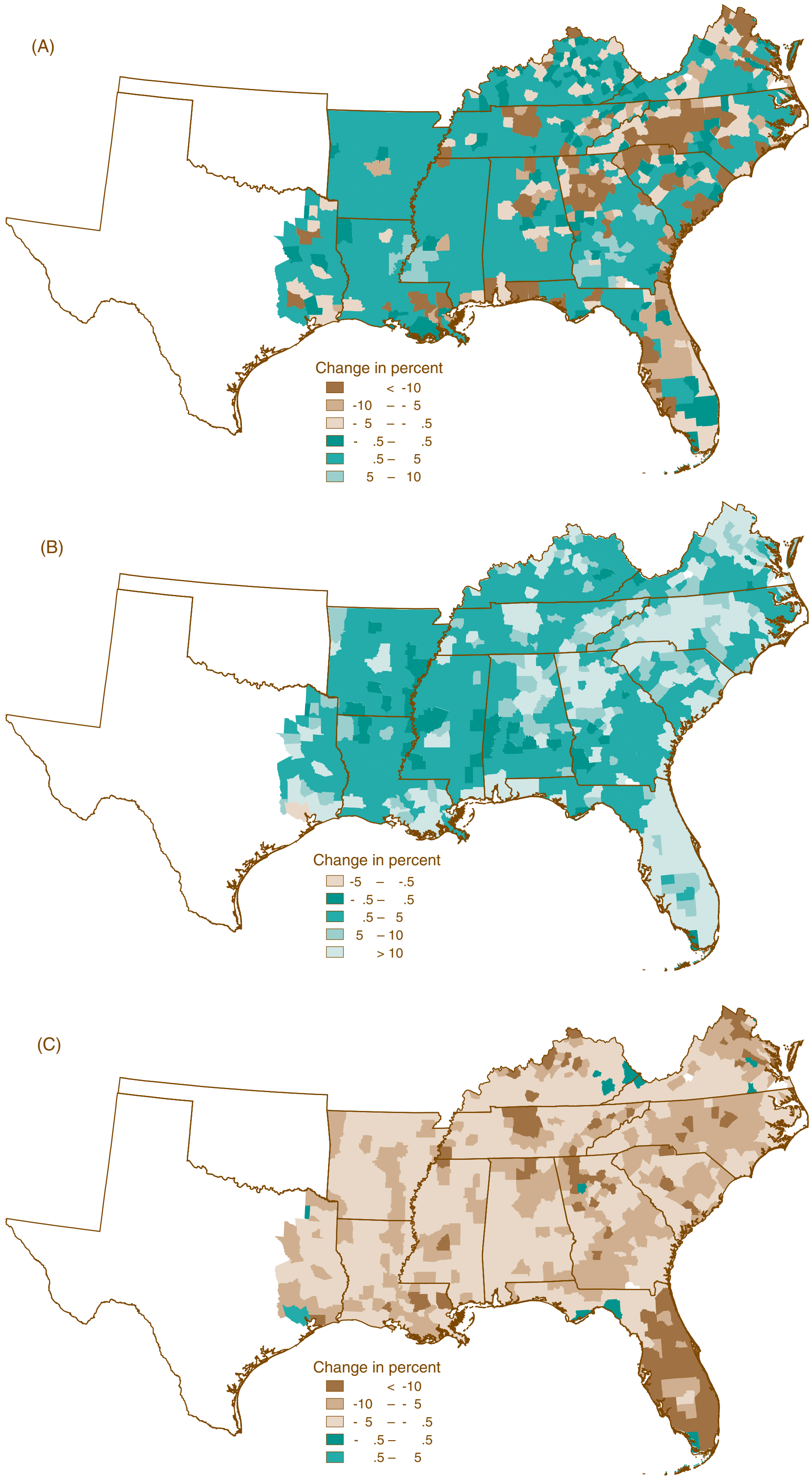


Figure 6.13—Forecast changes in percent under the base scenario of (A) forest, (B) urban, and (C) agricultural land uses by county for 1992 to 2020 [land use forecasting model described in Hardie and others (2000)].

Table 6.3—Change in the percent of area in forest and amount of forest area by ecological section, 1992-2020[a b]

Ecological section	Change	
	Acres	*Percent*
Southern Appalachian Piedmont	-3,508,238	-7.95
Southern Ridge and Valley	-298,941	-7.17
Atlantic Coastal Flatlands	-746,238	-5.32
Blue Ridge Mountains	-655,402	-4.98
Florida Coastal Lowlands (Eastern)	-230,977	-4.70
Central Ridge and Valley	-152,335	-4.63
Florida Coastal Lowlands (Western)	-205,895	-3.69
Southern Cumberland Plateau	-187,877	-3.46
Eastern Gulf Prairies and Marshes	-19,195	-2.00
Interior Low Plateau, Highland Rim	-338,960	-1.99
Northern Ridge and Valley	-126,901	-1.70
Interior Low Plateau, Bluegrass	-95,613	-1.57
Everglades	-54,216	-1.18
Coastal Plains and Flatwoods, Lower	-132,656	-0.24
Southern Unglaciated Allegheny Plateau	-3,891	-0.22
Southern Cumberland Mountains	-725	-0.03
Middle Atlantic Coastal Plain	-1,451	-0.02
Mid Coastal Plains, Western	30,829	0.13
Northern Cumberland Plateau	12,039	0.14
Northern Cumberland Mountains	5,525	0.43
Louisiana Coast Prairies and Marshes	32,686	0.44
Interior Low Plateau, Shawnee Hills	22,225	0.46
Ouachita Mountains	21,625	0.60
Upper Gulf Coastal Plain	73,832	1.07
Central Gulf Prairies and Marshes	15,306	1.38
Oak Woods and Prairies	97,270	1.96
Coastal Plains, Middle	1,149,225	3.08
Arkansas Valley	122,764	3.28
Ozark Highlands	197,008	3.55
Mississippi Alluvial Basin	872,002	3.61
Boston Mountains	130,610	3.64
Coastal Plains and Flatwoods, Western Gulf	277,915	3.89
Total	-3,698,650	

[a] Forecasts are for the base scenario (population, income, and housing forecasts along with a 35-percent price increase).
[b] Entries are sorted by change in percent from largest loss to largest gain. Data were developed by aggregating county-level observations for forest land use from the National Resource Inventory into their respective ecological sections as defined by Rudis (1999).

However, the largest block of potential gain in forest land would lie in the western one-third of the South. This area includes the southwestern quadrant of Alabama and nearly the entire States of Mississippi, Louisiana, and Arkansas. In this area, rural land use appears to be very sensitive to changes in relative returns to agricultural and forestry (fig. 6.14) (table 6.3).

As significant as the areas showing gains in forest area is a large contiguous portion of the region showing little response to increasing forest rent. This area reaches from the northern parts of South Carolina, Georgia, and Alabama to the northern boundary of the Assessment area.

Sensitivity analysis—A sensitivity analysis of the effect of timber price changes shows that the margin between agricultural and forest land uses could be relatively flexible. The urban growth scenario forecast a loss of about 12 million acres of forest land; the scenario with a 10-percent increase in real timber prices forecast a loss of about 8 million acres. If the real timber price were to increase by 20 percent from 1992 to 2020, forest land loss is forecast to be 3.5 million acres. A 30-percent real price increase results in essentially no net change in forest land in the South.

This sensitivity analysis has focused on upward movement in the timber-to-agriculture rent ratio. If this rent ratio were to fall—if agriculture rents rise relative to timber—we would expect the reverse. Forest land would move toward agricultural uses at the margin.

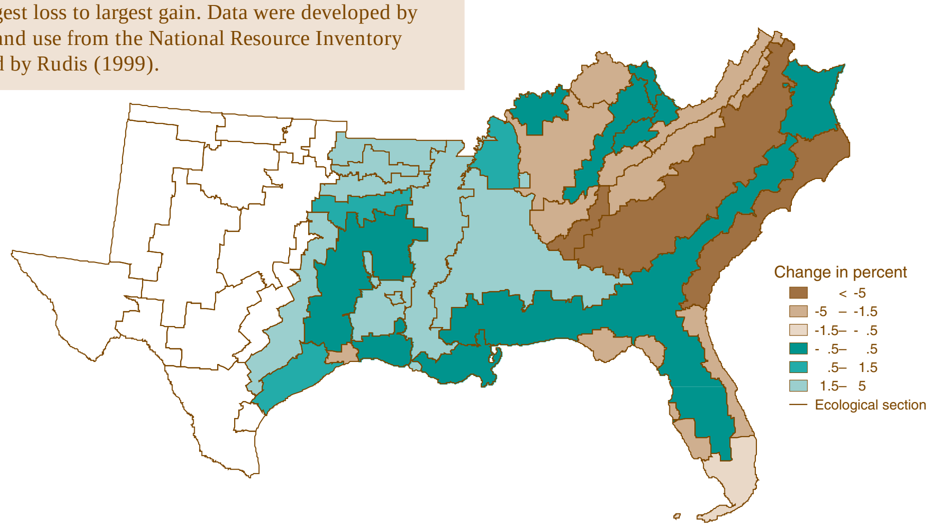


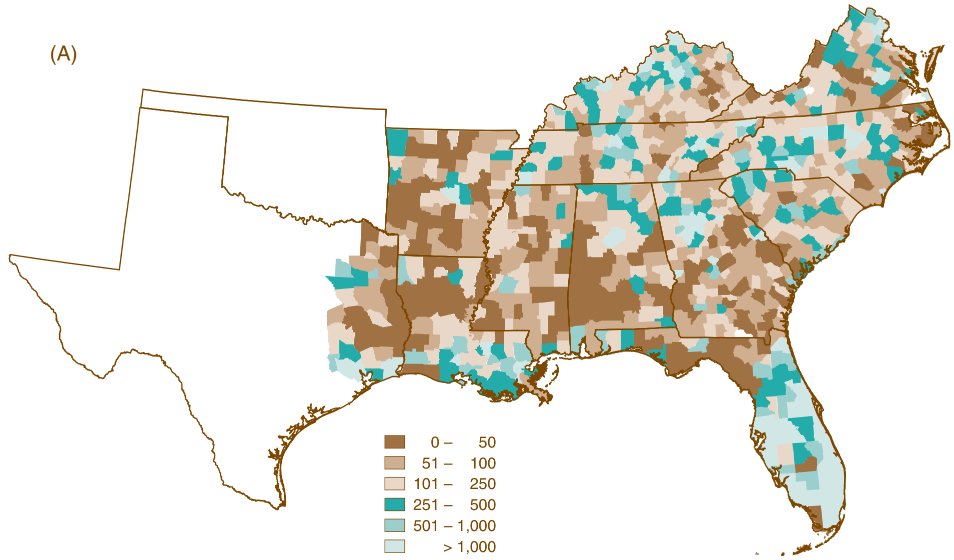
Figure 6.14—Forecast changes in percent of forest by ecological section for 1992 to 2020 under the base scenario [land use forecasting model described in Hardie and others (2000), county aggregation according to Rudis (2000)].

Forest Conditions

Forest population density—Forest population density (FPD) measures the number of people per square mile (ppsm) of forest in counties. The index ranges from about 20 ppsm in very rural areas of the South to more than 1,000 in urbanized areas. We consider 1,000 ppsm a "saturated" condition and cap FPD values at 1,000. As expected, FPD is highest near large cities (fig. 6.15A). Florida has the highest concentration of these saturated areas. Population density is very high throughout Florida, and forest cover is low in the southern half of the State. The largest contiguous area of very low FPD is in southwestern Alabama, where more than 20 counties have an FPD of less than 50 ppsm.

Three areas of the South with interstate highway corridors had relatively high FPD values in 1992: the Interstate-85 corridor from Raleigh/Durham, NC, to Atlanta, GA; the Interstate-65 corridor from Birmingham, AL, to Nashville, TN; and the Interstate-81 corridor from Chattanooga, TN, to Wytheville, VA. On the periphery of the region in northern Kentucky and Virginia and along the gulf coast, FPDs were also relatively high in 1992.

Forecasts to 2020 indicate continued outward growth of the urban centers of the South. A characteristic "doughnut" pattern of growth emerges around the cities of Atlanta, GA, Nashville, TN, Charlotte, NC, and Washington, DC (fig. 6.15B). Expansion in FPD would also be concentrated along the Atlantic Coast in South Carolina and Florida and along the gulf coast. Figure 6.16 shows the shift in the population profile of counties in the South. There is a strong movement to the right as 82 counties move out of the most rural category (FPD = 0 to100 ppsm) and 52 counties move into the saturated category (greater than 900 ppsm).



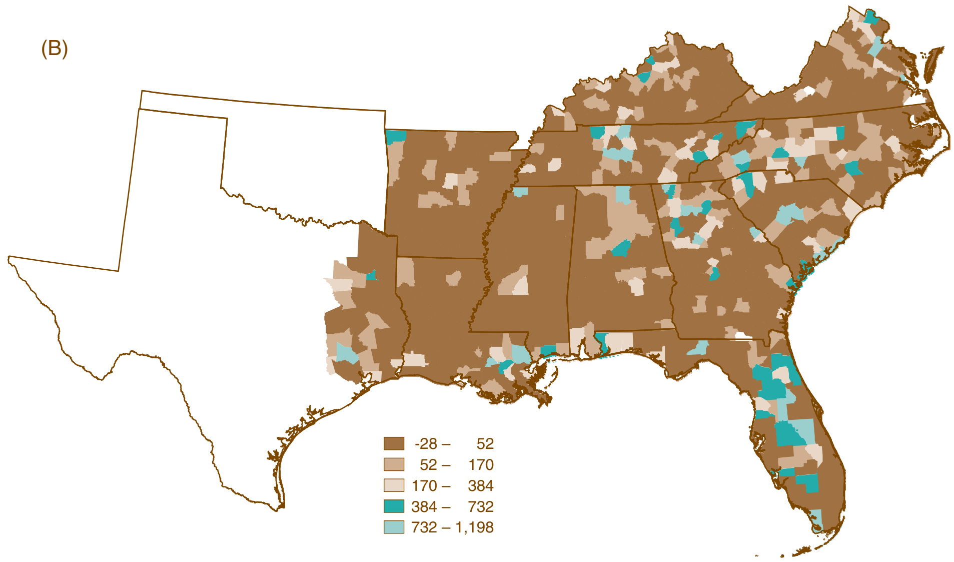


Figure 6.15—Forest population density index (FPD) in (A) people per square mile of forest by county for 1992 and (B) change in FPD for 1992 to 2020 [1992 forest land use from the National Resources Inventory (National Cartography and Geospatial Center (1998); 2000 forest use from the land use forecasting model described in Hardie and others (2000); population in 1992, U.S. Census Bureau (2002); and population in 2020 from county-level forecasts by NPA Data Service Inc. (1999)].

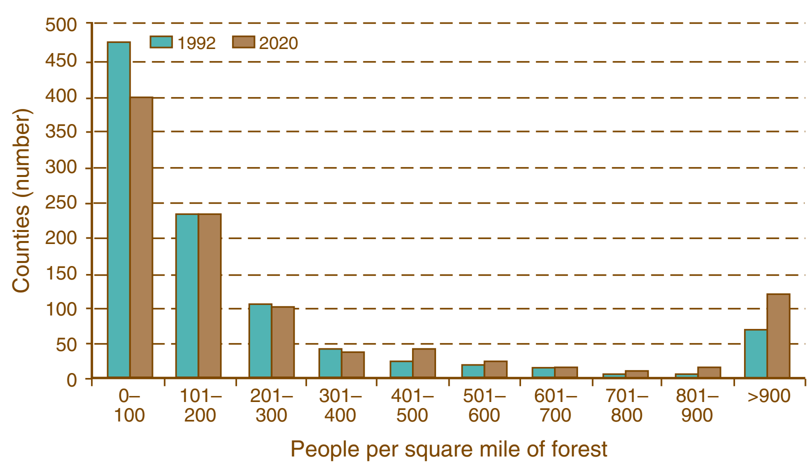


Figure 6.16—Numbers of counties in forest population density index classes, 1992 and 2020 [1992 forest land use from the National Resources Inventory (National Cartography and Geospatial Center (1998); 2000 forest use from the land use forecasting model described in Hardie and others (2000); population in 1992, U.S. Census Bureau (2002); and population in 2020 from county-level forecasts by NPA Data Service Inc. (1999)].

Landscape patterns—Maps of landcover in the early 1990s (fig. 6.17) reveal that, overall, the South is heavily forested and that the distribution of forest cover is highly variable. Two areas of the South have large blocks of counties with forest cover in excess of 80 percent of the landscape. One is the Blue Ridge Mountain Province from northern Georgia to the North Carolina-Virginia border. The other is the Cumberland Plateau/Southern Allegheny region stretching from central Tennessee (just west of Knoxville) to the Ohio River.

Areas with somewhat less forest cover than the Blue Ridge, but still substantial shares, are the Southern Appalachian Piedmont and the Gulf Coastal Plain (including nearly the entire State of Alabama). Even in the urbanizing areas of the Southern Appalachian Piedmont, forest covers a majority of the land. The other area of substantial contiguous forest cover is west of the Mississippi River in a block that stretches north from central Louisiana to the Ozark Mountains.

Forest cover does not dominate in important agricultural areas of the South. Agriculture is especially dominant in the Mississippi Alluvial Valley, in the northern and western portions of Kentucky, and in the southwestern corner of Georgia (fig. 6.17B).

Developed human uses are especially high in two areas. One is the Piedmont crescent stretching from Raleigh/Durham, NC, to Atlanta, GA. The other is peninsular Florida. Other areas with substantial clusters of urban cover are Nashville and Knoxville, TN, and Washington, DC. All of these cities are surrounded by relatively large "footprints" of urban use.

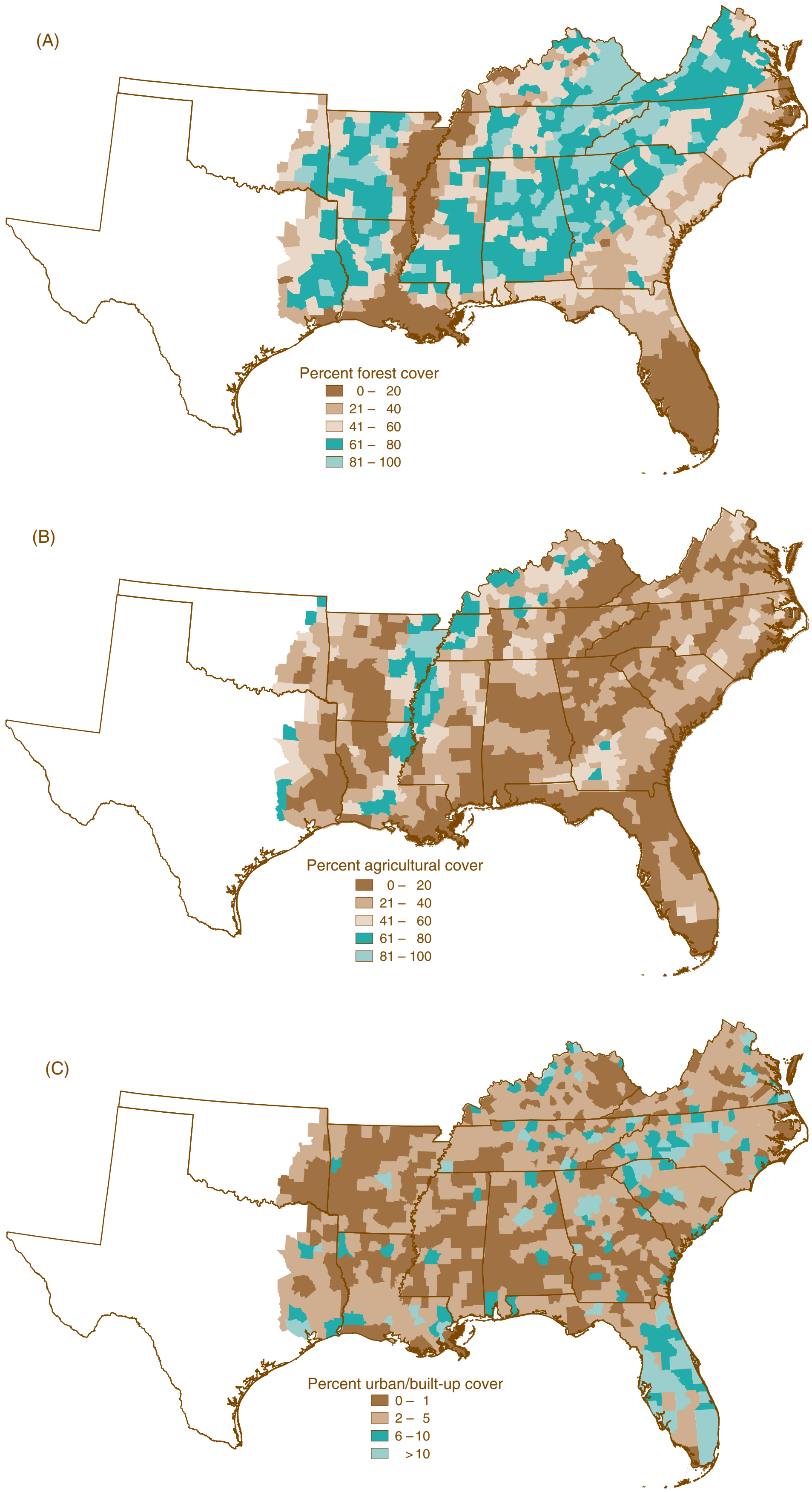


Figure 6.17—Shares of areas in southern counties in 1992 in: (A) forest, (B) agriculture, and (C) urban [Multi-Resolution Land Characteristics land-cover maps (Vogelmann and others 1998)].

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A high proportion of interior forest in a county is an indicator of relatively contiguous forest. The highest concentrations of interior forest at the fine scale (7-ha neighborhood) are found in the Blue Ridge Mountains and in the Cumberland Plateau/Allegheny Mountain sections of the South (fig. 6.18A). The Great Smoky Mountains National Park and a part of the Daniel Boone National Forest in Kentucky (just west of where Virginia, West Virginia, and Tennessee meet) are the cores of these two areas. Other areas where the share of interior forest is high include the Ouachita Highland/Ozark Mountain region of Arkansas, a region just north of Mobile Bay, and the Apalachicola area in the Panhandle of Florida. All of these areas include relatively high shares of land in either public or forest industry ownership.

The broad-scale measure of interior forest (56-ha neighborhood) highlights the relative scarcity of large contiguous areas of forest cover. At this scale, blocks of interior forest are found only in far western Virginia, the Cumberland Plateau, the Blue Ridge, and the mid-Coastal Plain west of the Mississippi River.

Forests that are highly fragmented are shaped primarily by human influences. The Southern Appalachian Piedmont has a relatively high proportion of land in an edge-dominated category, especially in North Carolina (fig. 6.19). Two other contiguous blocks are in an area spanning northern Mississippi and western Tennessee and an area west of the Cumberland Plateau between Alabama and Cincinnati, OH. In both of these areas, agricultural cover types break up the forest cover into small patches and reduce the amount of interior forest.

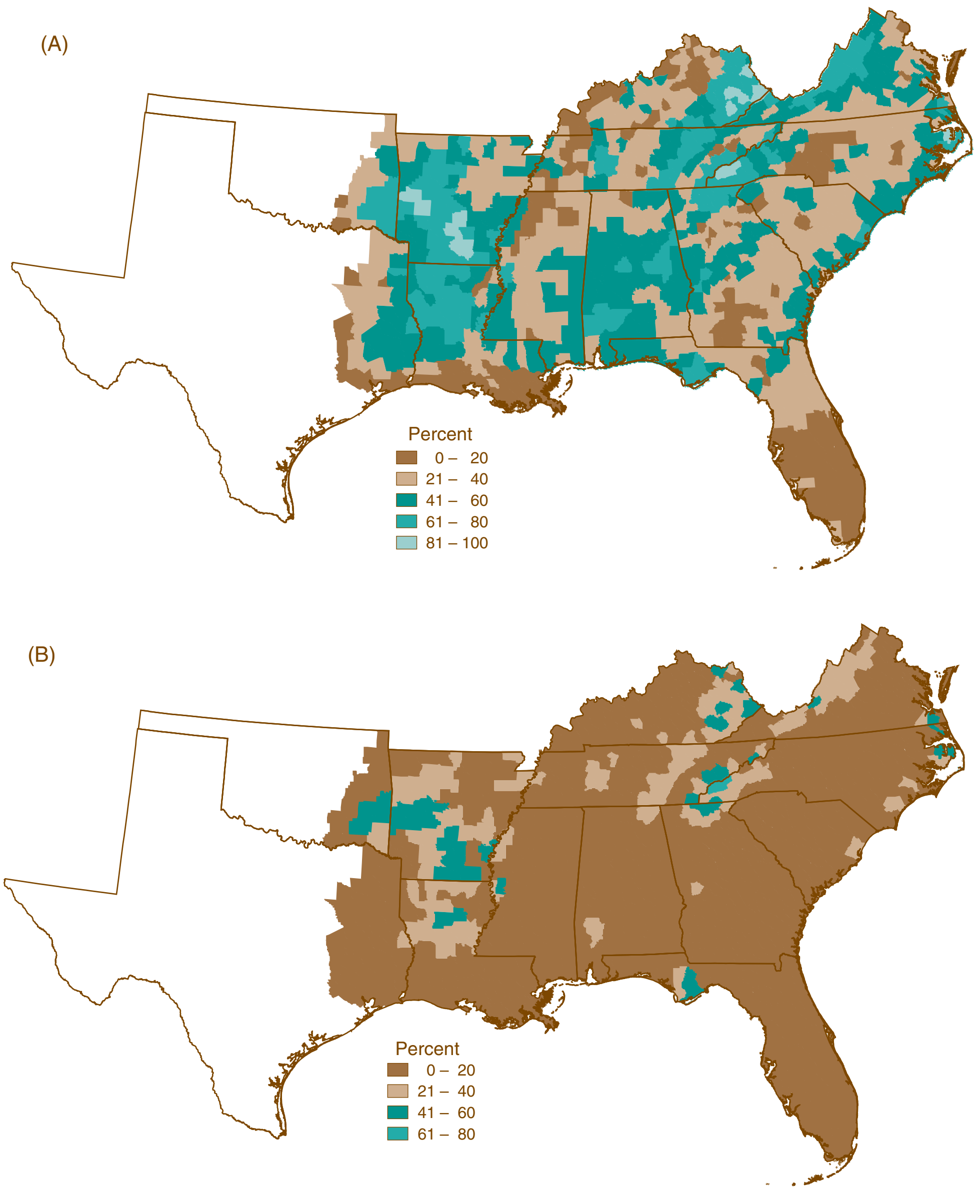

Figure 6.18—Shares of areas in counties classified as interior forest at (A) a fine scale (7-ha neighborhood), and (B) a broad scale (66-ha neighborhood) [Riitters and others (2000)].

Discussion and Conclusions

Compared to earlier periods, land use in the South has been fairly stable since 1945. The most notable exception is Florida, where developed land uses have expanded substantially. However, an evaluation of land use dynamics between 1982 and 1992 indicates that while total forest area has been stable, the stability is the result of substantial offsetting changes into and out of forest cover. As a result, much of the southern forest landscape has experienced significant change.

Two dominant forces strongly influenced recent land use changes: (1) urbanization driven by population and general economic growth and (2) changing relative returns to agriculture and timber production. We expect their influences to continue. As a result of anticipated population and economic growth, rural land will be converted to urban uses. As a result of increases in timber prices, some agricultural land will become forested. Depending on assumptions about future timber prices, forecasts of land uses indicate that the South could experience a net loss of from 8 to 12 million acres of forest land (roughly 5 to 8 percent) between 1992 and 2020.

Forest losses are likely to be concentrated in four areas: (1) the Piedmont and Mountain areas of North Carolina, (2) adjacent Piedmont areas of South Carolina and Georgia, (3) northern peninsular Florida, and (4) the Atlantic and gulf coastal areas. Other areas with substantial projected losses are around the cities of Nashville, TN, and Birmingham, AL, and in northern Virginia between Washington, DC, and Richmond, VA.

Gains in forest land at the expense of agriculture are likely in other regions of the South. In the eastern part of the

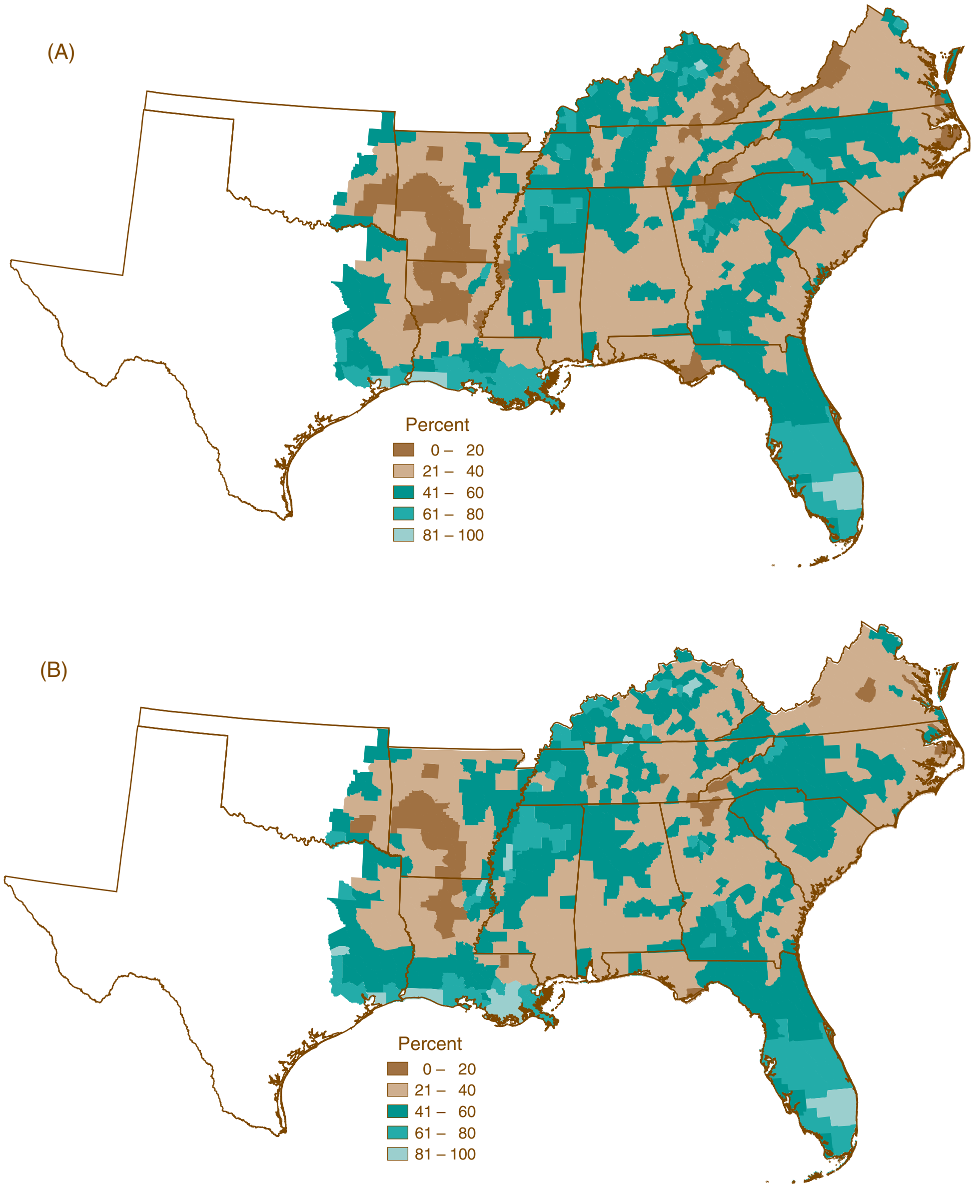

Figure 6.19—Shares of areas in southern counties classified as edge-dominated forest at (A) a fine scale (7-ha neighborhood), and (B) a broad scale (66-ha neighborhood) [Riitters and others (2000)].

South, forest gains are possible in two relatively small areas: (1) the upper Coastal Plain of Georgia and (2) an area centered on the boundary between North Carolina and Virginia in the Coastal Plain. In the western part of the South, forest gains are possible in the lower Gulf Coastal Plain in Alabama and in large portions of Arkansas, Mississippi, and Louisiana. Overall losses in forest in the eastern part of the region will likely be offset by gains primarily in the western part of the region.

This information may prove useful to policy analysts as they design afforestation policies. Cost-share programs such as the Forestry Incentives Program have long been popular conservation instruments in the United States. Our analysis suggests that certain areas are more prone to shift agricultural land to forest cover based on land quality and economics. Afforestation policies could be made more effective if they were targeted to these areas.

Forecasts of a forest population density index indicate that the potential influence of urban areas on forests extends far beyond city cores. As population density increases, so does the valuation and use of these forests. For example, forest benefits such as recreation and microclimate moderation increase in value in an urbanizing area. Timber management is generally inversely correlated with population density (Wear and others 1999). In these areas, therefore, timber harvesting is likely to be associated with land use conversions, and not with ongoing forest management. Another effect of urbanization is the division of large blocks of forests into smaller tracts or parcels. This increases the number of landowners, thereby complicating land management especially with regard to the use of fire.

While studies of growth and development tend to focus on urban areas, changes in population and forests are also occurring in the South's rural areas. As a result, the area in what has been called the "wildland-urban interface" is growing rapidly. Problems with interactions between people and forested systems therefore can also be expected to grow.

Evaluation of the spatial structure of forests identified parts of the South where the share of forest cover is relatively high but the forest is highly fragmented. This condition is especially common in some northern portions of the South, on the Southern Appalachian Piedmont, and in northern Florida. The effect of forest loss on habitat structure generally increases as the fragmentation of an area increases. In fragmented forests, small changes in the amount of forest cover may have disproportionate impacts on the connectivity of forested habitats (Turner and others 1989).

A synthesis of findings suggests several "hotspots" where changes in land use and forest conditions portend important negative impacts on the services provided by forests. They are:

- The Southern Appalachian Piedmont, especially along the Interstate-85 corridor between Raleigh/Durham, NC, and Atlanta, GA.
- The Blue Ridge Mountains in North Carolina.
- The Atlantic and gulf coastal areas.
- Northern peninsular Florida.

The same kind of effects are being concentrated in urbanizing areas surrounding the following cities:

- Nashville, TN
- Knoxville, TN
- Birmingham, AL
- Washington, DC

Needs for Additional Research

The land use forecasting described here was conducted at the county level of resolution, a rather coarse grain. Additional information about the implications for terrestrial ecosystems and water quality and aquatic ecosystems could be developed from analysis at a finer scale. Fine-scale analysis has been conducted for small areas by Wear and Bolstad (1998) and Turner and others (1996). Studies such as these address land use and cover at a cell size as small as 0.09 ha and can therefore provide direct linkage between land use choices and local ecological structure and impacts. Extending this scale of analysis, while expensive, could provide valuable and much more direct insights into the links between human activities and ecological consequences.

Additional work that links social demographics with land use and resource management decisions could provide additional insights into how social change might influence the flow of goods and services from forested ecosystems.

Acknowledgments

Thanks to my colleagues Peter Parks and Ian Hardie for their work in developing the land use model used in the chapter. Thanks also to Kurt Riitters for compiling the MRLC data and to David Butry for constructing the maps.

Literature Cited

Ahn, SoEun; Plantinga, Andrew J.; Alig, Ralph J. 2001. Historical trends and projections of land use for the South-Central United States. Res. Pap. PNW–RP–530. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Station. 20 p.

Alig, Ralph J. 1986. Econometric analysis of factors influencing forest acreage trends in the Southeast. Forest Science. 32(1): 119–134.

Alig, Ralph J.; Healy, Robert G. 1987. Urban and built-up land area changes in the United States: an empirical investigation of determinants. Land Economics. 63(3): 215–226.

Economic Research Service. 1996. Major land uses. [Database]. http://www.ers.usda.gov/data/sdp/view.asp?f=land/89003/. [Date accessed: August 14, 2002].

Hardie, Ian; Parks, Peter; Gottlieb, Peter; Wear, David. 2000. Responsiveness of rural and urban land uses to land rent determinants in the U.S. South. Land Economics. 76(4): 659–673.

Howard, James L. 1999. U.S. timber production, trade, consumption, and price statistics 1965–1997. Gen. Tech. Rep. FPL–GTR–116. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 76 p.

Jones, J. 1997. Cash rents for U.S. farmland 1960-1993 (computer file 90025). Washington, DC: U.S. Department of Agriculture, Economic Research Service. http://www.ers.usda.gov/data/sdp/view.asp?f=land. [Date accessed: August 13, 2002].

Jones, K.B.; Riitters, K.H.; Wickham, J.D. [and others]. 1997. An ecological assessment of the United States mid-Atlantic region: a landscape atlas. EPA/600/R97/130. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. [Number of pages unknown].

Loveland, T.R.; Shaw, D.M. 1996. Multiresolution land characterization: building collaborative partnerships. In: Scott, J.M.; Tear, T.; Davis, F., eds. Gap analysis: a landscape approach to biodiversity planning. Moscow, ID: U.S. Geological Survey: 83–89.

Murray, Brian C.; Abt, Robert C.; Wear, David N. [and others]. 2001. Land allocation in the Southeastern U.S. in response to climate change impacts on forestry and agriculture. World Resources Review. 13(2): 239–251.

National Cartography and Geospatial Center. 1998. Instructions for collecting the 1997 national resources inventory data. http://www.ftw.nrcs.usda.gov/nri/inst_toc.html. [Date accessed: August 14, 2002].

NPA Data Service, Inc. 1999. Regional economic projection series. Washington, DC: NPA Data Service, Inc. [Number of pages unknown].

Riitters, K.H.; Wickham, J.D.; Vogelmann, J.E.; Jones, K.B. 2000. National land-cover pattern data. Ecology. 81: 604.

Rudis, Victor A. 1999. Ecological subregion codes by county, conterminous United States. Gen. Tech. Rep. SRS–36. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 95 p.

Turner, M.G. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics. 20: 171–197.

Turner, M.G.; Gardiner, R.; Dale, V.H.; O'Neill, R.V. 1989. Predicting the spread of disturbance across heterogeneous landscapes. Oikos. 55: 121–129.

Turner, M.G.; Wear, D.N.; Flamm, R.O. 1996. Influence of landownership on land cover dynamics in the Southern Appalachian Highlands and the Olympic Peninsula. Ecological Applications. 6: 1150–1172.

Ulrich, Alice H. 1987. U.S. timber production, trade, consumption, and price statistics 1950–1985. Misc. Publ. 1453. Washington, DC: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 81 p.

U.S. Census Bureau. 2002. U.S. Census Bureau homepage. http://www.census.gov/. [Date accessed: August 14, 2002].

Vogelmann, J.E.; Sohl, T.; Howard, S.M. 1998. Regional characterization of land cover using multiple sources of data. Photogrammetric Engineering and Remote Sensing. 64: 45–47.

Wear, D.N.; Bolstad, P. 1998. Land use changes in Southern Appalachian landscapes: spatial analysis and forecast evaluation. Ecosystems. 1(6): 575–594.

Wear, D.N.; Liu, R.; Foreman, J.M.; Sheffield, R. 1999. The effects of population growth on timber management and inventories in Virginia. Forest Ecology and Management. 118: 107–115.

Wear, D.N.; Turner, M.G.; Naiman, R.J. 1998. Land cover along an urban-rural gradient: implications for water quality. Ecological Applications. 8(3): 619–630.

Wickham, J.D.; Norton, D. 1994. Mapping and analyzing landscape patterns. Landscape Ecology. 9: 7–23.

Williams, Michael. 1989. Americans and their forests: a historical geography. New York: Cambridge University Press. 599 p.

What are the attitudes and values of southern residents toward forests and their management, how have they changed over time, and how do they differ among demographic groups?

Chapter 7: Sociodemographics, Values, and Attitudes

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Key Findings

- When compared with the Nation, the South is more rural, nonwhite, and poorly educated, with lower median household income.
- From 1980 to 1990, total population increased at a higher rate in the South (14.16 percent) than in the Nation (9.78 percent). Most of the increase was in the major cities such as Atlanta, GA, Austin, TX, Dallas, TX, and Miami, FL, and along the eastern coastline. Some decrease occurred in the Southern Appalachians, the Mississippi River Basin, and the western Texas and Oklahoma Panhandle.
- Southern areas with population losses since 1980 are generally more rural, have more nonwhite residents, and have lower median household incomes than areas with population increases.
- Southern residents hold stronger (more intense) values about public than private forests. Among four values of forests mentioned to respondents, the one considered most important was clean air, and the one rated as least important was wood production.
- Southern residents have moderately strong proenvironmental attitudes. They favor additional funding of environmental protection and stricter environmental laws and regulations.
- A review of the related literature reveals a strong and fundamental shift over the past two decades in public values about forests and their management. Values have shifted away from a commodity-oriented, anthropocentric approach to forest management and toward inclusion of natural biological factors in a biocentric approach.
- Southern women and younger people have stronger biocentric values about forests and stronger proenvironmental attitudes than men and older people. There are only minor differences in environmental attitudes and values between urban and rural residents, and by length of residence, land ownership, race, and region within the South.

Introduction

The values and attitudes that the public holds toward the natural environment, forests, and forest management have become increasingly important over the past few decades. Indeed, it has been argued that the core problem facing traditional forestry is a need to adjust to changing social and environmental values (Bengston 1994). Information about values and attitudes equips managers to deal with potential conflicts among stakeholders, to establish policies and goals, and to define broad strategies.

Understanding environmental values and attitudes begins with the social, economic, and demographic composition of the public. A value is defined here as a standard that provides the criteria for determining what is desirable or undesirable (Brown 1984, Rokeach 1973). An attitude is a learned predisposition toward some object or action (Fishbein and Ajzen 1975). Attitudes are driven by and are more transient than values. Forest values concern the good or relative worth of forests. Attitudes evaluate the desirability of forest uses, such as timber harvesting and recreation.

Methods

Three different methods were used to answer the question in this chapter. In the first method, population data for 1980, 1990, and 1999 (projected) were mapped at the county scale using ArcView 3.1 (Environmental Systems Research Institute 1996). In the second method, 1,423 randomly sampled residents of the 13 States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia) were interviewed by telephone. In the third method a literature review was conducted.

Nine social, economic, and demographic population variables were mapped (table 7.1). Median household incomes were adjusted with the Consumer Price Index (Woodrow 2000) to reflect 1980-dollar amounts. For all variables, percent change was computed as (1990 value minus 1980 value)/1980 value.

The telephone survey (about 2 minutes) was part of the National Survey on Recreation and the Environment (NSRE) (about 20 minutes) administered by the Human Dimensions Research Laboratory at the University of Tennessee during fall 2000. Telephone numbers were generated from a random-digit dialing sample of valid telephone exchanges. Respondents were selected by asking for the resident in the household, over the age of 16 years, with the most

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Table 7.1—Social, economic, and demographic characteristics of residents in the United States and in the South

	National		Southern	
Variable	1980	1990	1980	1990
Total population (no.)	226,545,805	248,709,873	67,973,072	77,597,917
Median household income ($)	16,647	30,056	14,675	25,192
Rural (%)	26.3	24.8	33.4	31.7
Female (%)	51.4	51.3	41.4	51.4
Nonwhite (%)	16.9	19.6	21.6	22.9
Hispanic (%)	6.5	8.8	6.4	8.4
Blue-collar (%)	47.0	41.9	49.6	44.2
Some college (%)	31.8	45.3	29.0	42.1
Over 55 years (%)	20.9	21.0	20.6	21.1

recent birthday. By including refusals from known eligible respondents, i.e., household residents known to have the most recent birthday, and deleting the number of "never-contacted" numbers, the response rate was 52.3. This percent includes partial completes of 3.6, hearing-impaired respondents of 2.0, callbacks that were never recontacted of 3.0, and known eligible refusals of 39.1.

Forest values were measured in two ways: (1) as individual-preference "assigned" values, which provide a measure of the relative worth or importance of forest objects, and (2) as individual-preference "held" values, which provide a measure of the relatively enduring conception of the "good" (or bad) related to forests. Both approaches were used, because there is no consensus in the social-psychological literature as to which is better. In both approaches, the same four objects (taken from Xu and Bengston 1997) were used: wood products (utilitarian), clean air (life support), scenic beauty (aesthetic), and heritage (spiritual). Respondents were asked to rank the four objects in their relative order of importance from highest (most important) to lowest (least important) for (1) private forests and (2) public forests. The most important object was given a score/rank of 1 and the least important 4. The four objects were read to the respondents in a random order by the interviewer to avoid bias in ranking. For held values, each object was rated from 1 "agree" to 4 "disagree," where low scores indicated a higher value.

Three types of environmental attitudes were assessed. First, attitudes toward environmental protection were measured by asking respondents, "Do you think that we're spending too much, too little, or about the right amount of money on protecting the environment?" Second, attitudes toward environmental laws were measured by asking respondents, "At present, do you think that our environmental laws and regulations have gone too far, not far enough, or have struck about the right balance?" Third, general environmental concern (including private property issues) was measured using a modified (10-item) version of the New Environmental Paradigm (NEP) scale (Dunlap and Van Liere 1978), in which 6 of the original 12 items were deleted (due to sexist and/or outdated terminology), 1 item was reworded, and 4 new items were added (table 7.2). The 10 items in the modified NEP scale were rated on a 5-point response scale from "strongly agree" to "strongly disagree" with a midpoint of "neither." Possible scores ranged from 10 (representing a highly favorable attitude) to 50 (highly unfavorable attitude). Cronbach's alpha for the modified NEP was 0.70.

Urban residents were oversampled because of the greater proportion of southern residents in metropolitan areas. One-way ANOVA (using the Scheffe method) and Pearson Correlation in SPSS/PC+ (Statistical Packages for the Social Sciences 1998) were used to examine differences in

Table 7.2—Items and descriptive statistics for the modified New Environmental Paradigm scale

Item	n	Mean[a]	Standard deviation
Human skill and resource will ensure that we do not make the earth unlivable[b]	645	3.36	1.4
Humans are severely abusing the environment	681	1.73	1.06
Humans have the right to modify the natural environment to suit their needs	676	2.65	1.47
Humans were meant to rule over nature	678	2.56	1.57
Humans will eventually learn enough about how nature works to be able to control it[b]	661	2.61	1.48
If things continue on their present course, we will soon experience a major ecological catastrophe[b]	658	2.21	1.33
The balance of earth is delicate and easily upset	672	1.68	1.04
The so-called "environmental crisis" has been greatly exaggerated[b]	660	2.73	1.45
We are approaching the limit to the number of people this earth can support	633	2.5	1.44
When humans interfere with nature, it often produces disastrous consequences	681	1.84	1.12

[a] Items were measured using a 5-point response scale of (1) strongly agree to (5) strongly disagree.
[b] New or modified item (from the original New Environmental Paradigm scale).
Source: Dunlap and Van Liere 1978

environmental attitudes and forest values among the social and demographic groups.

Data Sources

Population data for 1980 were taken from the Census CD 1980 Version 2.0 (Geolytics 2000) and for 1990 and 1999 from the Census CD Maps Release 3.0 (Geolytics 1999). Projections for 1999 were available for total population, gender, and race.

The NSRE data were provided through the USDA Forest Service Southern Research Station in Athens, GA. The literature review covered journal articles, government documents, books, conference proceedings, and monographs published since 1990.

Results

Social, Economic, and Demographic Characteristics of Southern Residents

From 1980 to 1990, total population increased at a higher rate in the South (14.16 percent) than in the United States (9.78 percent) (table 7.1). The South is more rural, more nonwhite, less educated, and more blue collar, with lower median household income, than the national average.

The southern population is concentrated along the coasts; in Piedmont cities, including Atlanta, GA, Charlotte, NC, and Columbia, SC; and in the major cities of Texas (Austin, Dallas, and Houston) and Florida (fig. 7.1). Between 1980 and 1999 (figs. 7.2 and 7.3) these major metropolitan areas received the greatest percentage increase in population, while there were decreases in the Mississippi River Basin, in the western Texas and Oklahoma Panhandle, and in parts of the Southern Appalachians. In 1990 (fig. 7.4), education levels (percent of residents attending some college) were generally lowest in the central interior and north-central region of the South. Between 1980 and 1990, education levels generally increased throughout the South, with the strongest gains along the eastern coast and in the major metropolitan areas (fig. 7.5).

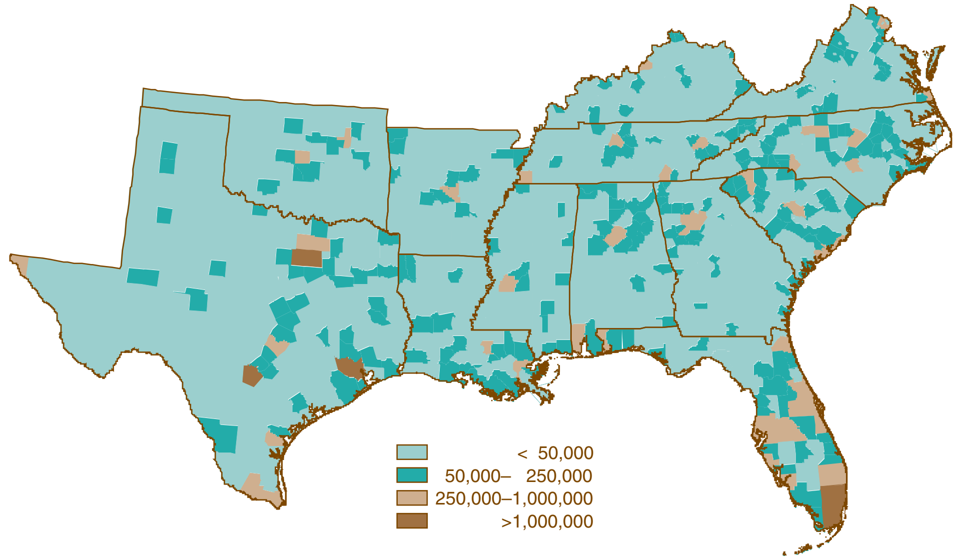

Figure 7.1—Total population in the South, 1990.

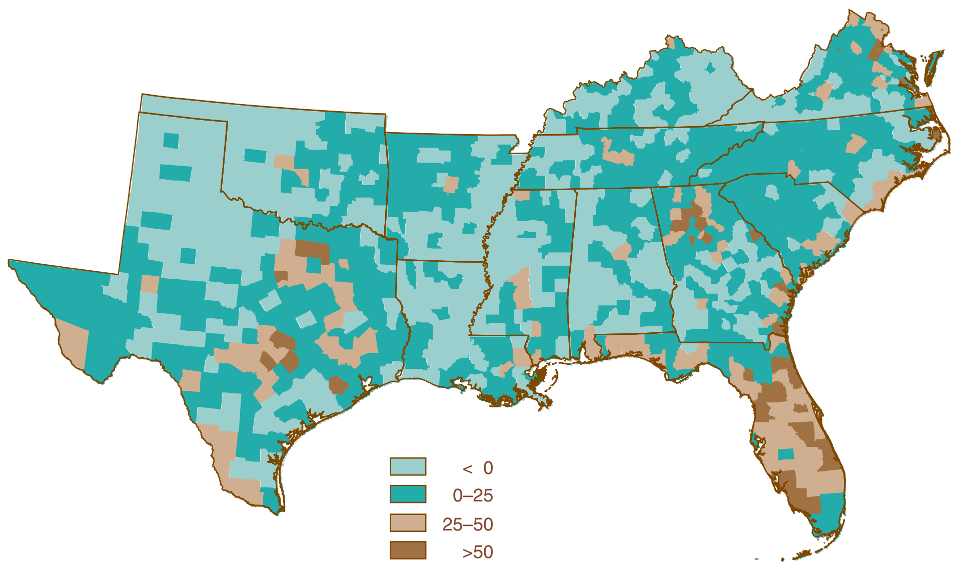

Figure 7.2—Percent change in total population in the South, 1980 to 1990.

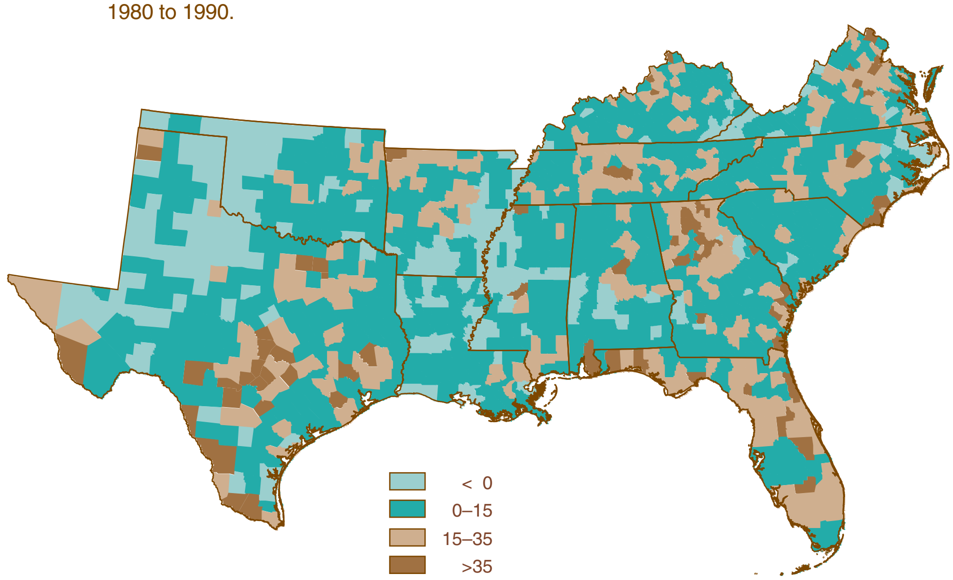

Figure 7.3— Percent change in total population in the South, 1990 to 1999.

The highest concentrations of rural residents in 1990 occurred in the Southern Appalachians, parts of the Mississippi River Basin, and the western Texas and Oklahoma Panhandle (fig. 7.6). Overall, the entire region experienced a general decrease in rural residency between 1980 and 1990 (fig. 7.7).

Areas with the highest percentage of residents older than 55 years in 1990 include Arkansas, Oklahoma, central Texas, and southern and central Florida (fig. 7.8). From 1980 to 1990, many areas of the South experienced an increase in elderly population, except for the metropolitan cities of Atlanta, GA, Dallas and Houston, TX, and Miami, FL (fig. 7.9). In 1990, the highest percentage of blue-collar workers occurred in western Texas and Oklahoma, parts of the Southern Appalachians, and the central and north-central areas of the South (fig. 7.10). Since 1980, the percent of blue-collar workers has decreased in the South as a whole, but increases have occurred in parts of Mississippi and the western Texas and Oklahoma Panhandle (fig. 7.11). In 1990 there were more women than men in most counties across the South, with the highest concentrations in the center of the region and the lowest in parts of Texas, Florida, and the Southern Appalachians (fig. 7.12). Between 1980 and 1999, the percent of women largely decreased throughout the South, except in small pockets of the coast (with the exception of Florida) and the Texas and Oklahoma Panhandle (figs. 7.13 and 7.14).

In 1990, the highest concentrations of Hispanics were in west Texas (along the Mexico border) and south Florida (fig. 7.15). Between 1980 and 1990, the highest increases in Hispanic populations occurred throughout Texas and Florida. Modest gains occurred in Oklahoma, Georgia, and North Carolina (fig. 7.16). In 1990, the percentage of nonwhite residents was highest in a broad band from the Mississippi River Basin through the Piedmont to the Carolinas coast. The lowest concentrations were in the north-central region of the South, the Southern Appalachians, central Texas, and the Florida coasts (fig. 7.17). The largest increase in nonwhite populations from 1980 to 1990 occurred in western

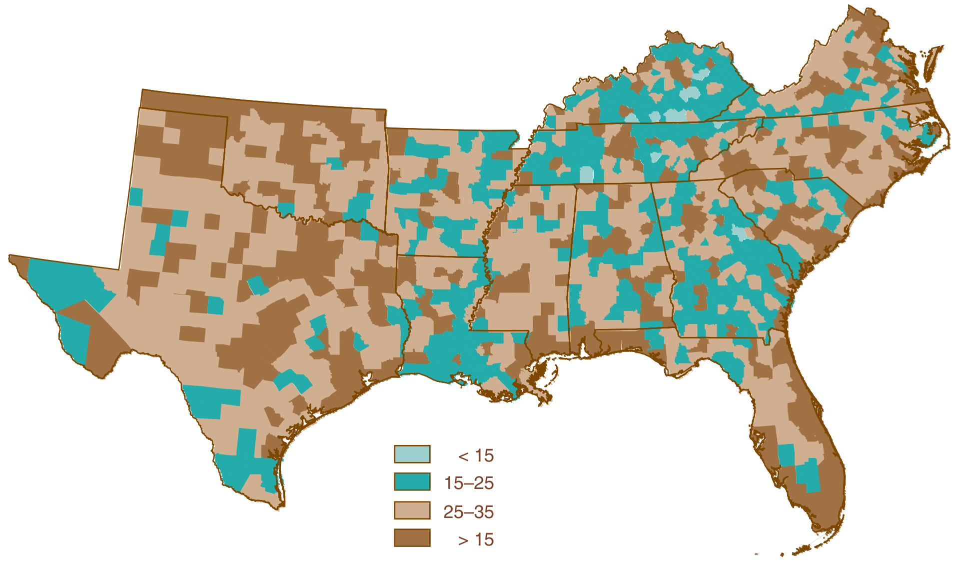

Figure 7.4—Percent of residents attending college in the South, 1990.

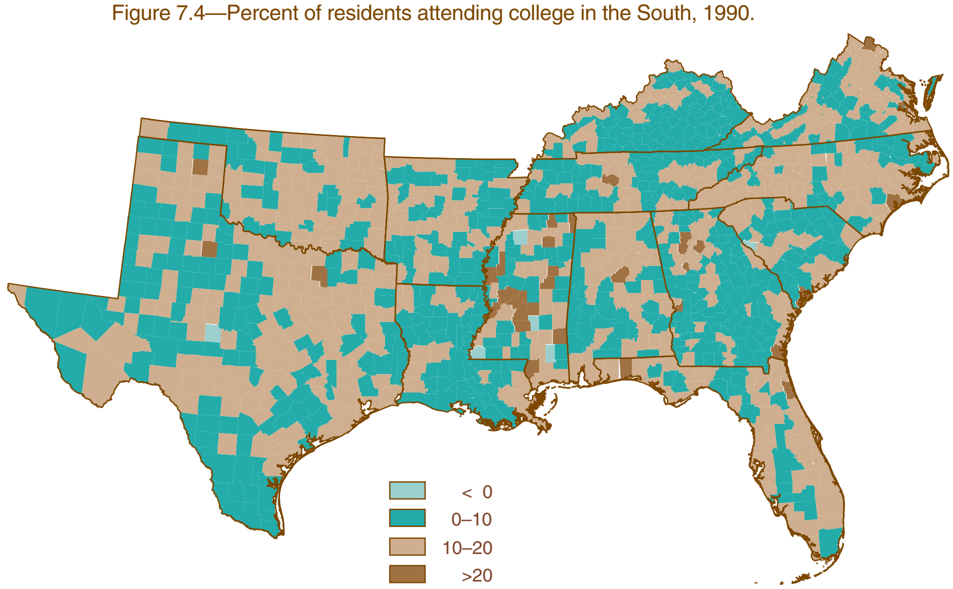

Figure 7.5—Change in percent of residents attending college in the South, 1980 to 1990.

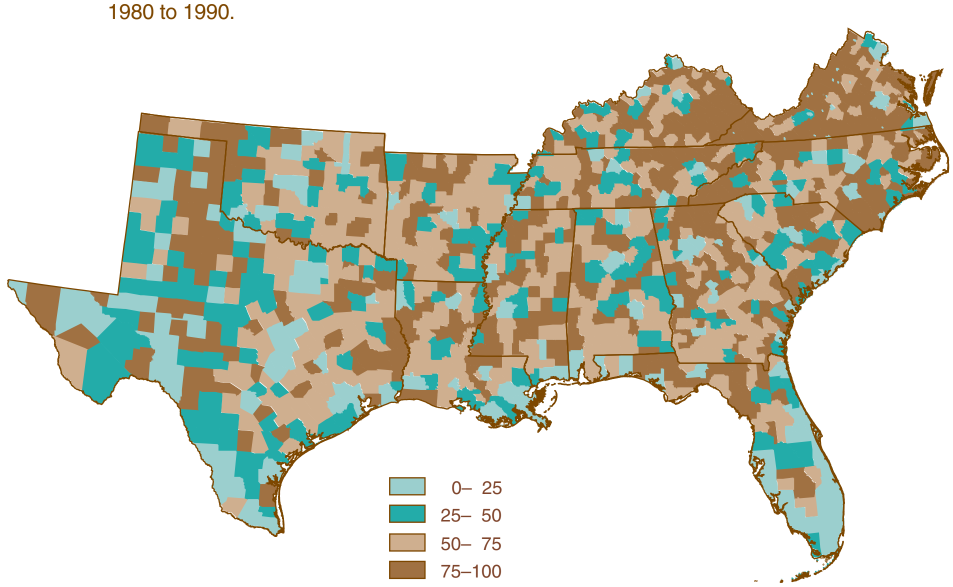

Figure 7.6—Percent of rural residents in the South, 1990.

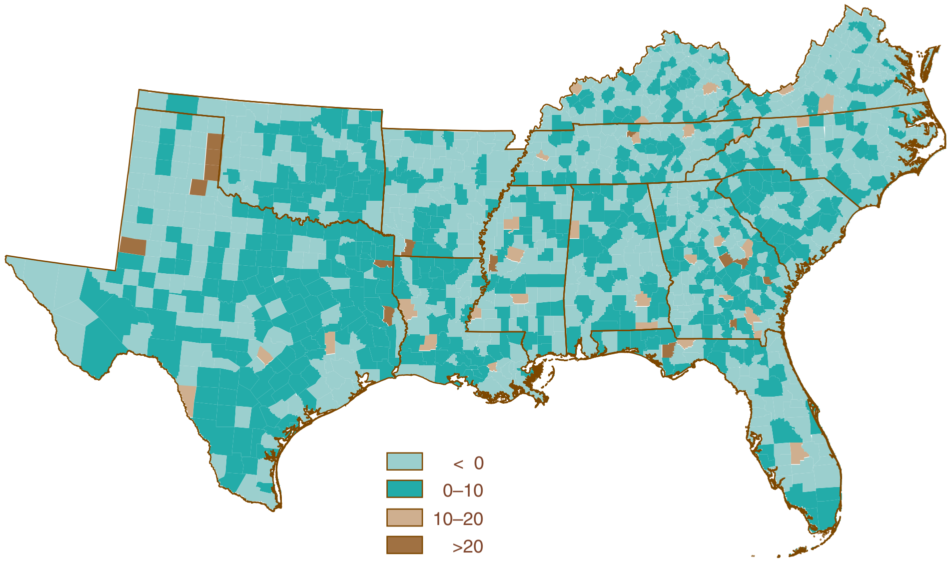

Figure 7.7—Change in percent of rural residents in the South, 1980 to 1990.

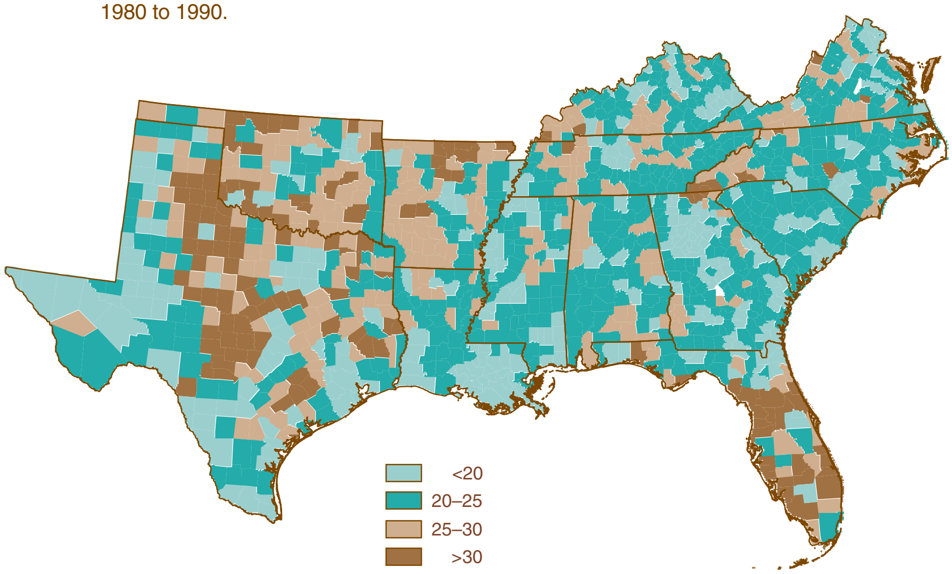

Figure 7.8—Percent of residents in the South over 55 years of age, 1990.

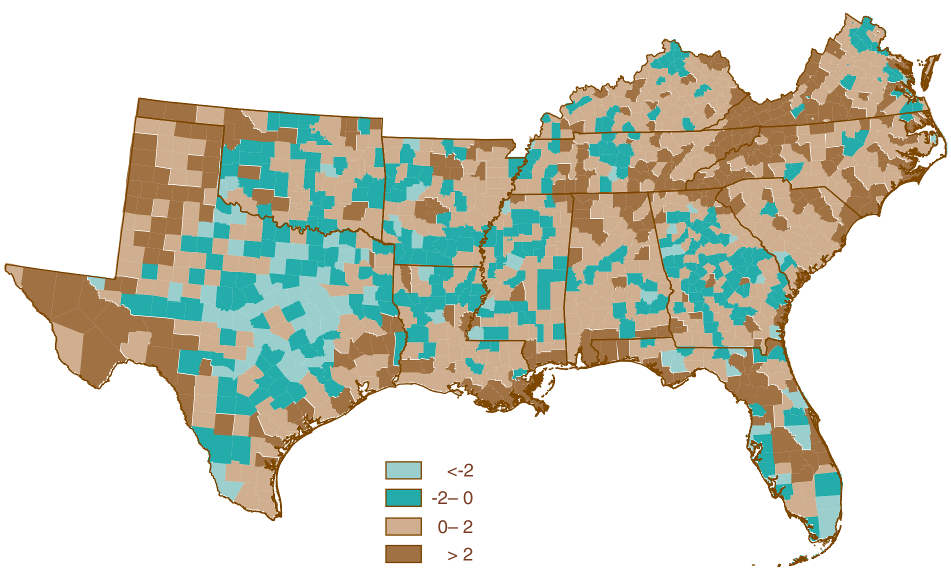

Figure 7.9—Change in percent of residents in the South over 55 years of age, 1980 to 1990.

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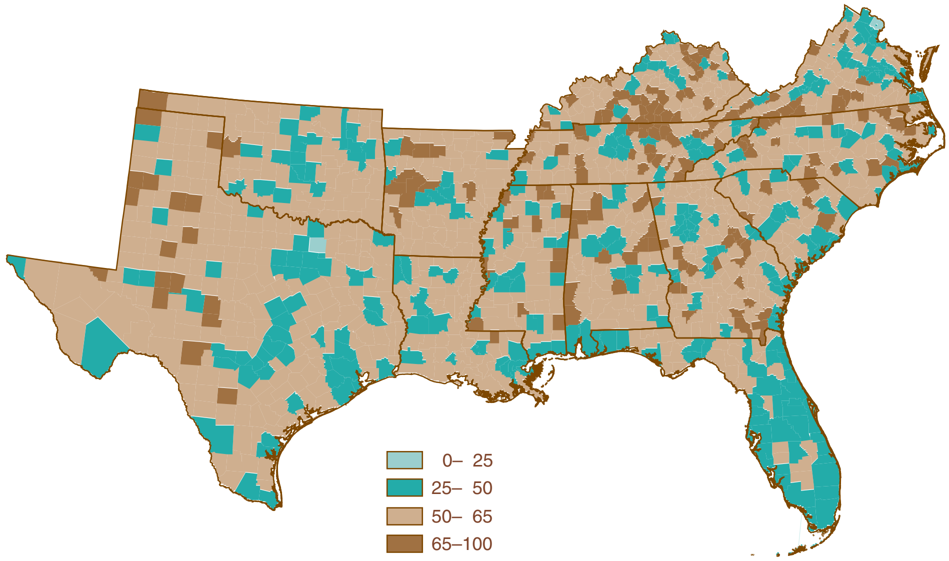

Figure 7.10—Percent of blue-collar workers in the South, 1990.

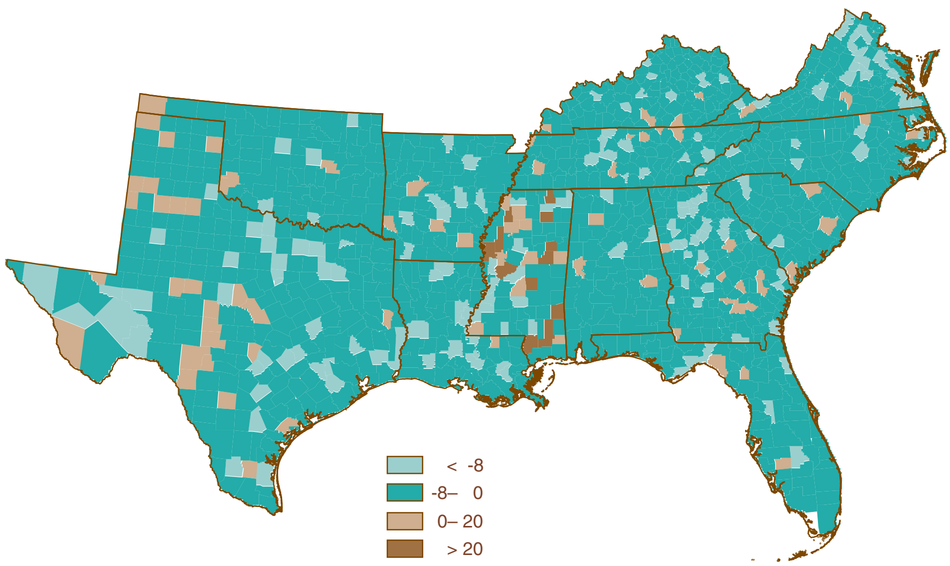

Figure 7.11—Change in percent of blue-collar workers in the South, 1980 to 1990.

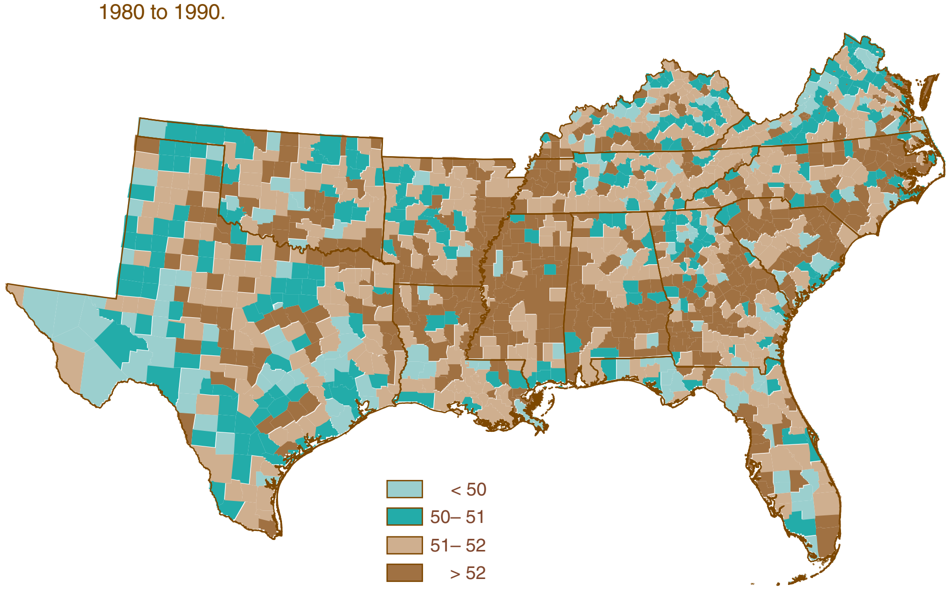

Figure 7.12—Percent of female residents in the South, 1990.

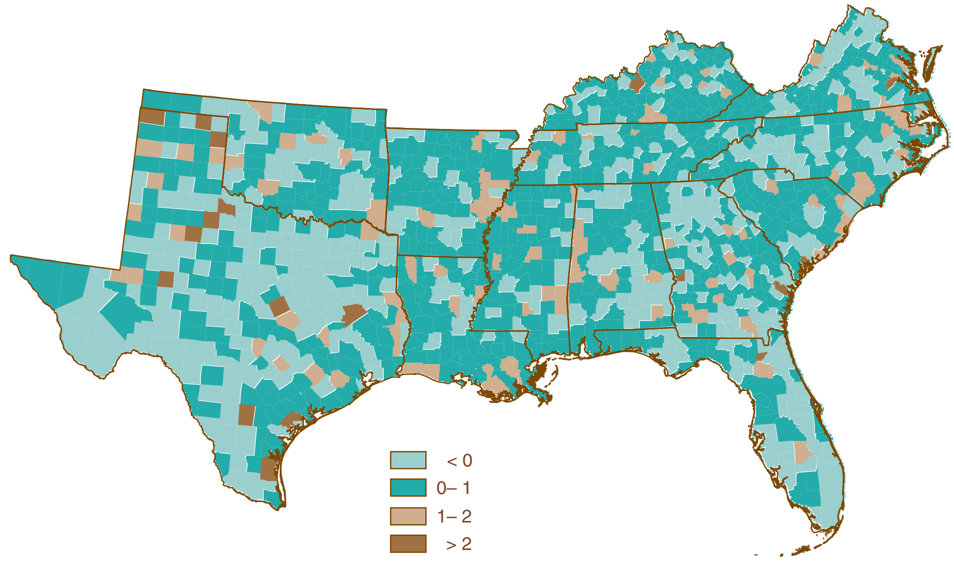

Figure 7.13—Change in percent of female residents in the South, 1980 to 1990.

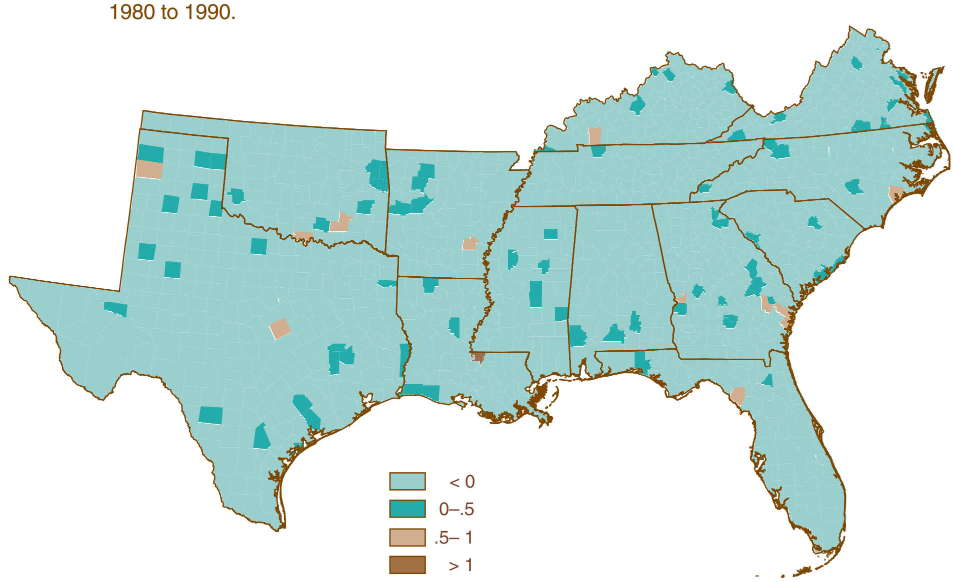

Figure 7.14—Change in percent of female residents in the South, 1990 to 1999.

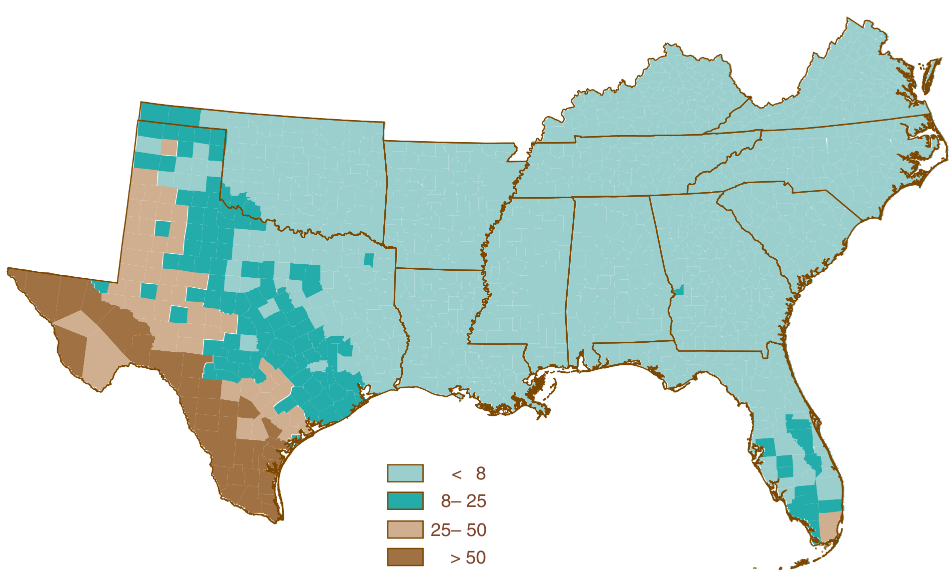

Figure 7.15—Percent of Hispanic residents in the South, 1990.

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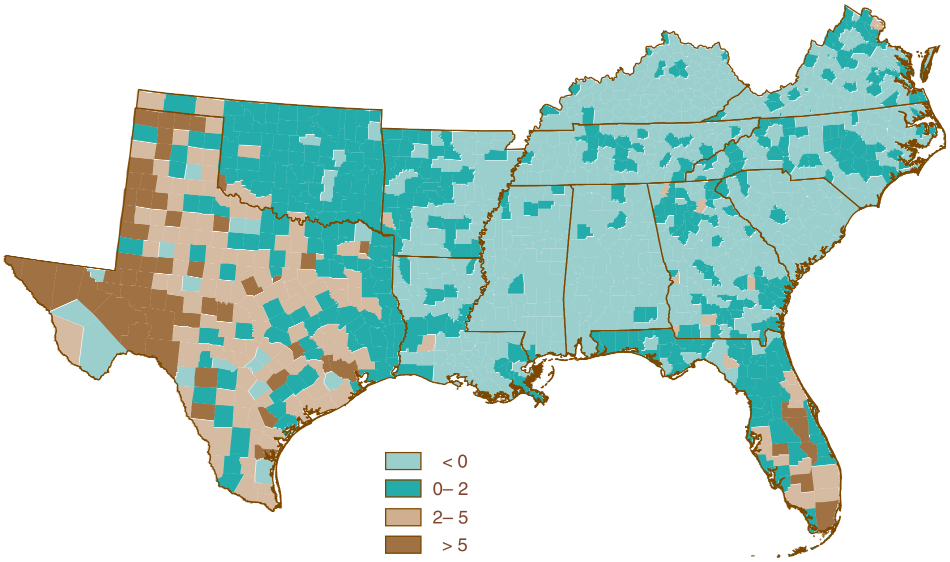

Figure 7.16—Change in percent of Hispanic residents in the South, 1980 to 1990.

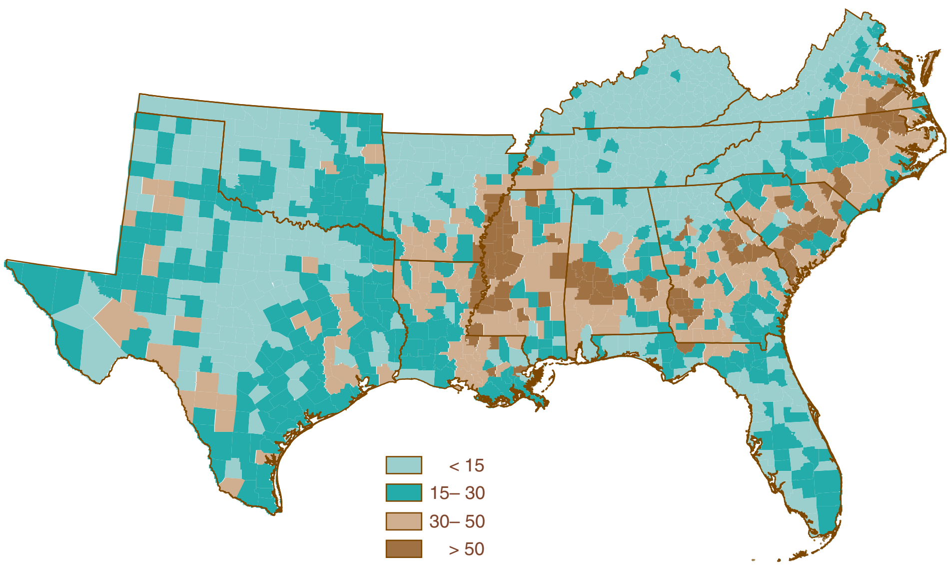

Figure 7.17—Percent of nonwhite residents in the South, 1990.

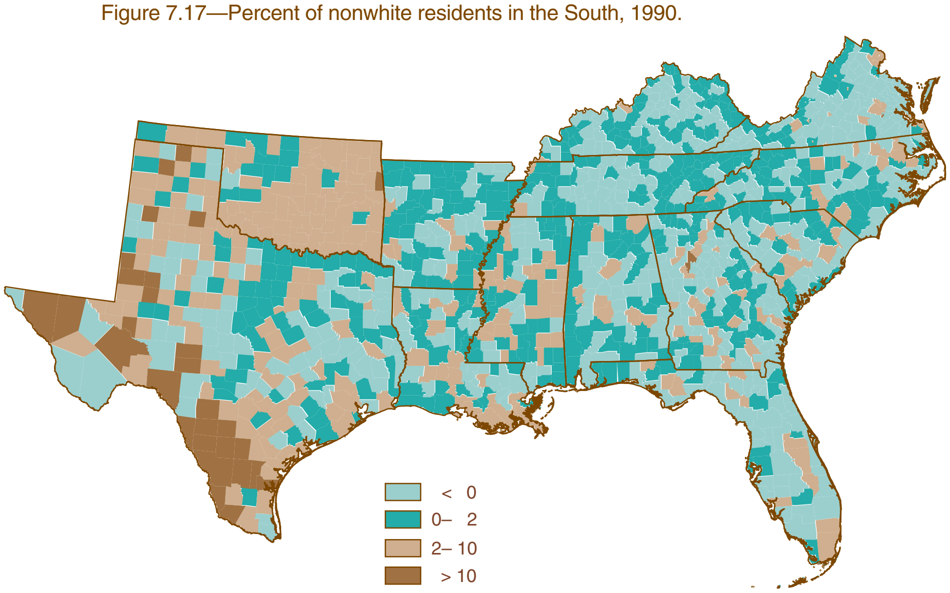

Figure 7.18—Change in percent of nonwhite residents in the South, 1980 to 1990.

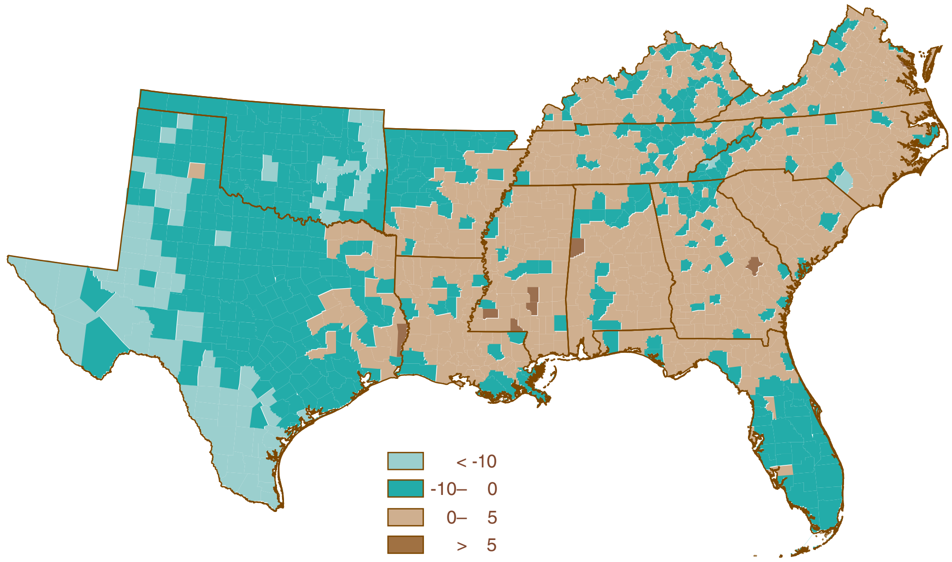

Figure 7.19—Change in percent of nonwhite residents in the South, 1990 to 1999.

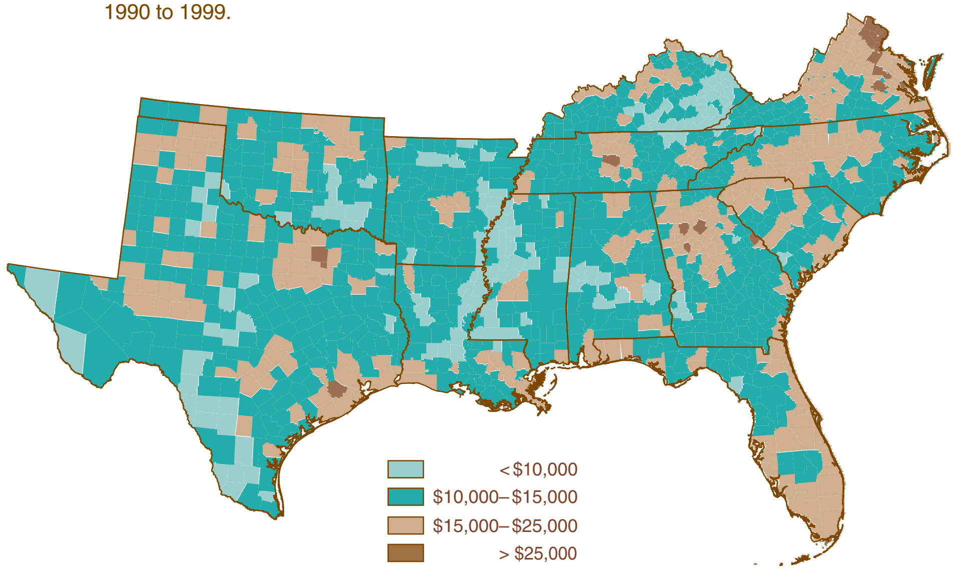

Figure 7.20—Median household income (adjusted by Consumer Price Index) in the South, 1990.

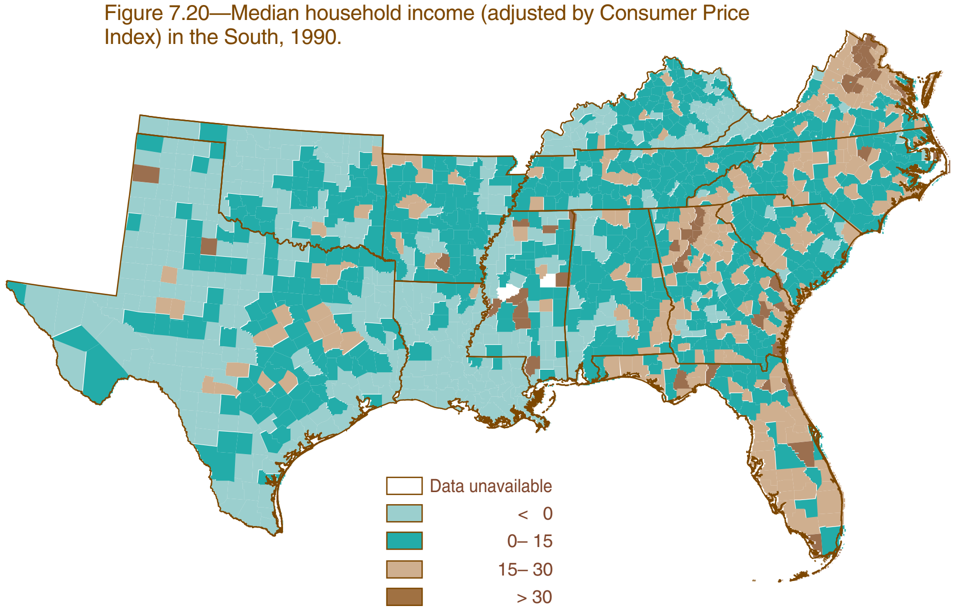

Figure 7.21—Percent change in median household income (adjusted by Consumer Price Index) in the South, 1980 to 1990.

Texas, Oklahoma, and the Mississippi River Basin (fig. 7.18). From 1990 to 1999, the rates of increase in nonwhite populations reversed, with the greatest increase along a broad band from the Mississippi River Basin through the Piedmont to the Carolinas coast (fig. 7.19).

In 1990, the wealthiest areas in the South were primarily in major cities, while the poorest areas tended to be rural (fig. 7.20). Between 1980 and 1990, the highest gains in median household income were in the eastern half of the South, especially in major cities, and along the Carolinas and Florida coast. Decreases occurred in the Mississippi River Basin, the Southern Appalachians, Texas, Oklahoma, and the coast of Louisiana (fig. 7.21).

Attitudes and Values Toward Public and Private Forests

Wood production was generally rated as the least important of the four values associated with forests, and clean air as the most important (tables 7.3 and 7.4). However, some differences existed between public and private forests. The provision of wood products was valued higher for private forests than for public forests, and the provision of clean air was valued lower for private forests than for public forests. These results suggest that respondents held stronger values about public than private forests. They strongly believe that public forests should provide clean air and should not provide wood products, but do not hold such restrictive values for private forests.

A majority of respondents felt that (1) "too little" was being spent on protecting the environment (62.5 percent) versus only 9.2 percent who reported "too much," and (2) environmental laws had gone "not far enough" (45.5 percent) versus only 13.1 percent who thought that the laws had gone "too far." A mean score of 23.75 on the modified NEP (range from 10 to 50) suggests a moderately strong proenvironmental attitude. Individual item scores for the modified NEP are shown in table 7.2.

Table 7.3—Assigned and held values of public forests

	n	Mean	Rank	Standard deviation
Assigned values[a]				
Wood products	510	3.32	4	0.93
Clean air	525	1.51	1	.75
Scenic beauty	521	2.44	2	.97
Cultural and natural heritage	512	2.69	3	.98
Held values[b]				
Wood products	520	3.14	4	1.5
Clean air	530	1.25	2	.68
Scenic beauty	527	1.22	1	.57
Cultural and natural heritage	520	1.25	2	.59

[a] Assigned forest values were ranked from most (1) to (4) least important.
[b] Held forest values were rated from (1) agree to (4) disagree.

Table 7.4—Assigned and held values of private forests

	n	Mean	Rank	Standard deviation
Assigned values[a]				
Wood products	498	2.77	3	1.20
Clean air	505	1.62	1	.78
Scenic beauty	498	2.65	2	1.00
Cultural and natural heritage	492	2.91	4	.96
Held values[b]				
Wood products	513	2.31	4	1.31
Clean air	524	1.37	1	.71
Scenic beauty	526	1.71	3	.96
Cultural and natural heritage	521	1.66	2	1.00

[a] Assigned forest values were ranked from most (1) to (4) least important.
[b] Held forest values were rated from (1) agree to (4) disagree.

Environmental Attitudes and Values by Social and Demographic Characteristics

Area of residence—Three groups were sampled: urban (n = 804), near urban (n = 459), and rural (n = 160). With one exception, there were no significant differences between the three groups in rating the four objects (wood products, clean air, scenic beauty, and heritage). The single exception was that rural residents rated scenic beauty as a more important object of public forests than did near-urban residents. There were no significant differences between the three groups in their attitudes toward the environment. Overall, results suggest that where people live in the South (in an urban or rural area) is not related to their values of forests or attitudes toward the environment.

Intergenerational differences—Three age groups (generations) were measured: < 24 years (n = 201), 25 to 49 years (n = 699), and 50+ years (n = 501). Ages of respondents ranged from 16 to 94 years old. Overall, age influenced public values toward forests and environmental attitudes. In evaluating private forests, the youngest generation (16 to 24 years) placed significantly less importance on wood products and significantly more on scenic beauty than did the oldest generation (50+ years). For public forests, the youngest generation valued scenic beauty significantly higher than did the oldest generation. Younger people were significantly more likely than older people to believe (1) that we are spending too little to protect the environment, and (2) that environmental laws have not gone far enough. There were no significant differences between the three age groups on the modified NEP scale. Overall, however, younger people tended to have more biocentric values in regard to forests than did older people.

Length of residency—Length of residency was measured by asking respondents to specify the number of years that they had lived where they are (range from 0 to 87 years, mean = 18.92 years). There were no significant correlations between length of residency and (1) valuation of public or private forests or (2) environmental attitudes.

Land ownership—Respondents were asked to indicate if they or their spouse owned any rural tract of 10 acres or more. Almost one-fifth (18.6 percent, n = 202) reported that they owned such a tract. With one exception, there were no significant differences between rural landowners and nonlandowners regarding forest values. The exception was that landowners rated wood products as a more important object of private forests than did nonlandowners. Furthermore, there were no significant differences between the two groups in attitudes toward the environment. Overall, results suggest that land ownership has relatively little bearing on southern residents' valuation of forests or attitudes toward the environment.

Gender—Women (n = 829) exhibited significantly stronger proenvironmental attitudes (as measured by the modified NEP) than men and were more likely than men to believe that (1) we had spent too little on the environment and (2) laws and regulations had not gone far enough. Men valued private forests for wood production significantly more than did women, while women valued public forests for scenic beauty significantly more than did men. Overall, women demonstrated more biocentric values and proenvironmental attitudes than men.

Race—Overall, there were minor differences between whites (n = 1162) and nonwhites (n = 203) in forest values and environmental attitudes. Nonwhites placed significantly higher importance on wood production and clean air values of public forests than whites, but whites rated public forests as more important for scenic values than did nonwhites.

Regions within the South—Of the 9 ecological divisions within the South (Rudis 1999), only 5 divisions had a sample size of greater than 30 respondents: Hot Continental (n = 273), Subtropical (inland) (n = 484), Subtropical (coastal) (n = 113), Prairie (n = 144), and Temperate Steppe (n = 91). For this reason, no further analysis was conducted.

Broad Changes in Environmental Attitudes and Values

A review of the literature revealed a strong and fundamental shift in public valuation of forests over the past two decades (e.g., see Bengston 1994, Bengston and Fan 1999, Cramer and others 1993, Manning and others 1999, Rolston and Coufal 1991, Steel and Lovrich 1997, Steel and others 1994, Tarrant and Cordell 1997, Xu and Bengston 1997). Support has shifted away from a commodity-oriented, anthropocentric approach to forest management and toward a more inclusive and diverse (commodity and noncommodity) biocentric approach. For the past 100 years, forest management has endorsed a resource conservation philosophy that emphasizes wise human use and development of resources, dominance of economic over noneconomic values, and human control over nature (Bengston 1994, Steel and others 1994). The change to a biocentric philosophy of forest management recognizes multiple values (which include traditional uses as well as nonuses) of forests, the production of human and nonhuman benefits, and the importance of public involvement in management decisions. Steel and Lovrich (1997) argued that the movement toward a biocentric approach to forests and forest management in North America reflects a postindustrial society in which higher order needs for self-development and self-actualization have supplanted subsistence needs that are satisfied through material acquisition. Factors that have contributed to this change include a shift in population from rural to urban areas, an increase in economic growth, and technological innovations.

Overall, research findings support (1) a relative decline in utilitarian forest values, (2) a concomitant increase in valuing life-support aspects of forests in the past decade, and (3) more favorable attitudes toward noncommodity forest issues and objectives (see Bengston and Fan 1999, Cordell and others 1996, Cramer and others 1993, Manning and others 1999, Steel and others 1997, Xu and Bengston 1997). In one of the few studies that focused specifically on the South, Cordell and others (1996) showed that Southern Appalachian residents exhibited moderately stronger proenvironmental values and attitudes than the national average. For example, more Southern Appalachian respondents were against increasing timber harvesting on private land (46.5 percent) than were in favor (35.8 percent), and a large majority were against timber harvesting on public lands (72.1 percent) compared with those in favor (17.6 percent). These results are consistent with our findings that wood production was valued as least important of the four objects associated with private or public forests. Other studies also reveal a relatively high level of environmental concern among southern residents. For example, a University of North Carolina (1993) study reported that 48 percent of southern respondents (versus 43 percent of nonsoutherners) felt that the environment had become worse in the past 10 years, and 13 percent (versus 19 percent of nonsoutherners) felt that the environment had improved. In a University of South Carolina (1992) study, 81 percent of South Carolina residents indicated that it was more important to maintain an acceptable level of water quality than to increase the number of jobs in the State. In other work, Bengston and Fan (1999) found that the most strongly held attitudes about roads in national forests were that they provide recreation access and contribute to ecological damage. While commodity-related benefits

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such as access for timber harvesting or mining were rated less important than noncommodity values such as access for recreation, eastern (including southern) residents placed higher value on commodity benefits than did western and Intermountain residents. Nonindustrial private forest (NIPF) landowners account for about 70 percent of the forest land in the South and 58 percent in the Nation as a whole. A majority of southern NIPF landowners report that they manage their forests for economic and noneconomic nontimber attributes (Bourke and Luloff 1994, Sinclair and Knuth 2000).

Discussion and Conclusions

Except for the Mississippi River Basin and western Texas, southerners are becoming more numerous, better educated, more urbanized, and wealthier. There also remains a larger (albeit decreasing) proportion of women than men across the region. Together, these factors may explain why southern residents favor biocentric values over economic and utilitarian uses of forests. For example, biocentric values were notably higher (in the NSRE sample) among women than men (as well as among younger than older people). Other studies also found: (1) an overall increase in proenvironmental attitudes from the mid-1980s to a peak in recent years (Dunlap 1991, Dunlap and Scarce 1991, Steel and Lovrich 1997) and (2) higher proenvironmental attitudes and values among female, educated, and urban residents (e.g., Kellert and Berry 1987, Steel and Lovrich 1997, Steel and others 1994). Kellert and Berry (1987), for example, found gender to be the most important demographic influence on wildlife values, in regard to which men demonstrated significantly stronger utilitarian and scientific beliefs, while women had higher moralistic and humanistic beliefs. In other work, Dunlap and Scarce (1991) report findings showing that environmental concern is highest among female, educated, and urban residents.

By managing forests for nonhuman as well as human values, foresters can (1) introduce biological ecosystem management approaches that are socially and politically acceptable (Bengston 1994), (2) refine measurement techniques to recognize the total (economic and noneconomic) value of forests to society, (3) include a broader spectrum of interested publics in the decisionmaking process (Tarrant and others 1997), and (4) reduce potential conflict and resistance to management practices by responding to public views and opinions (Steel and others 1994). Furthermore, these goals must also be considered in light of the extensive industrial and nonindustrial private land that exists in the South, recognizing the multiple and varied outcomes desired by each landowner. Identifying the publics' valuation of and attitudes toward forests is a first step in understanding the complexities of providing for multiple outcomes of our public and private forests and in addressing the potential costs and benefits to all foresters when making land management decisions.

Needs for Additional Research

The social, demographic, and economic database for the South will need to be updated with information from the 2000 Census. Future studies should address the reasons for southern residents' environmental attitudes and forest values. With that kind of information, ways may be found to generate future support for forest management actions in the South.

At least two limitations to the study should be identified. First, many of the questions on the survey were narrowly focused; for example, the various forest uses were presented as mutually exclusive when, in fact, there are probably complementary relations among the various uses. Second, the respondents' use of the forest products was not examined; for example, the extent to which people may enjoy wood and paper products.

Acknowledgments

The authors thank Dr. Gary Green and Becky Stephens, project manager and administrator, respectively, for the NSRE 2000.

Literature Cited

Bengston, D.N. 1994. Changing forest values and ecosystem management. Society and Natural Resources. 7: 515–533.

Bengston, D.N.; Fan, D.P. 1999. Roads on the U.S. national forests. Environment and Behavior. 31: 514–539.

Bourke, L.; Luloff, A.E. 1994. Attitudes toward the management of nonindustrial private forest land. Society and Natural Resources. 7: 445–457.

Brown, T.C. 1984. The concept of value in resource allocation. Land Economics. 60: 231–246.

Cordell, H.K.; Helton, G.; Tarrant, M.A.; Redmond, C. 1996. Communities and human influences in Southern Appalachian ecosystems: the human dimensions. In: The Southern Appalachian assessment social/cultural/economic technical report. Rep. 4 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 220 p.

Cramer, L.A.; Kennedy, J.J.; Krannich, R.S.; Quigley, T.M. 1993. Changing Forest Service values and their implications for land management decisions affecting resource-dependent communities. Rural Sociology. 58: 475–491.

Dunlap, R.E. 1991. Trends in public opinion toward environmental issues: 1965–1990. Society and Natural Resources. 4: 285–312.

Dunlap, R.E.; Scarce, R. 1991. The polls—poll trends: environment problems and protection. Public Opinion Quarterly. 55: 651–672.

Dunlap, R.E.; Van Liere, K.D. 1978. The new environmental paradigm. Journal of Environmental Education. 9: 10–19.

Environmental Systems Research Institute, Inc. 1996. Arc View GIS. Version 3.1. Redlands, CA: Environmental Systems Research Institute, Inc. 350 p.

Fishbein, M.; Ajzen, I. 1975. Belief, attitude, intention, and behavior. Reading, MA: Adison-Wesley.

Geolytics. 1999. Census maps [CD-ROM]. Release 3.0. East Brunswick, NJ: Geolytics.

Geolytics. 2000. Census 1980 [CD-ROM]. Version 2.0. East Brunswick, NJ: Geolytics.

Kellert, S.R.; Berry, J.K. 1987. Attitudes, knowledge and behaviors toward wildlife as affected by gender. Wildlife Society Bulletin. 15: 363–371.

Manning, R.; Valliere, W.; Minteer, B. 1999. Values, ethics, and attitudes toward national forest management: an empirical study. Society and Natural Resources. 12: 421–436.

Rokeach, M. 1973. The nature of human values. New York: The Free Press.

Rolston, H.; Coufal, J. 1991. A forest ethic and multivalue forest management. Journal of Forestry. 89: 35–40.

Rudis, V.A. 1999. Ecological sub-region codes by county, coterminous United States. Gen. Tech. Rep. SRS-36. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 95 p.

Sinclair, K.D.; Knuth, B.A. 1999. Nonindustrial private forest landowner use of geographic data: a precondition for ecosystem-based management. Society and Natural Resources. 13: 521–536.

Statistical Packages for the Social Sciences.1998. Base manual. Version 9.0. Chicago: Statistical Packages for the Social Sciences, Inc. 939 p.

Steel, B.S.; List, P.; Shindler, B. 1994. Conflicting values about Federal forests: a comparison of national and Oregon publics. Society and Natural Resources. 7: 137–153.

Steel, B.S.; List, P.; Shindler, B. 1997. Managing Federal forests: national and regional public orientations. In: Steel, B.S., ed. Public lands management in the West. Westport, CT: Greenwood Publishing: 17–46.

Steel, B.S.; Lovrich, N.P. 1997. An introduction to natural resource policy and the environment: changing paradigms and values. In: Steel, B.S., ed. Public lands management in the West. Westport, CT: Greenwood Publishing: 3–15.

Tarrant, M.A.; Bright, A.D.; Cordell, H.K. 1997. Attitudes toward wildlife species protection: assessing moderating and mediating effects in the value-attitude relationship. Human Dimensions of Wildlife. 2: 1–20.

Tarrant, M.A.; Cordell, H.K. 1997. The effect of respondent characteristics on general environmental attitude-behavior correspondence. Environment and Behavior. 29: 618–637.

University of North Carolina. 1993. Southern focus poll. Chapel Hill, NC: University of North Carolina, Center for the Study of the America South, Institute for Research in Social Science. 128 p.

University of South Carolina. 1992. South Carolina omnibus survey. Columbia, SC: University of South Carolina, Survey Research Center. 78 p.

Woodrow, G. 2000. Consumer price index, 1913–. http://woodrow.mpls.frb.fed.us/research/data/us/calc/hist1913.cfm. [Date accessed: July 8, 2002].

Xu, Z.; Bengston, D.N. 1997. Trends in national forest values among forestry professionals, environmentalists, and the news media. Society and Natural Resources. 10: 43–59.

Chapter 8:
Policies, Regulations, and Laws

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How do current policies, regulations, and laws affect forest resources and their management?

Key Findings

Federal Income Tax Incentives

Since the Federal tax code was enacted in 1913, provisions have been added to encourage improved management and stewardship of private forest land; but forest owners and policymakers believe additional incentives still are needed.

■ Incentives that alter the tax treatment of reforestation expenses have the potential to improve management and stewardship on nonindustrial private forests (NIPFs), because they are specifically linked to reforestation of harvested areas. Examples of such incentives include immediate deduction of reforestation expenses, enhanced amortization provisions, and Green Accounts.

■ Extending tax provisions and incentives already available to owners who manage their forest holdings for a profit to owners who manage primarily for environmental or social purposes would encourage and enable additional owners to make stewardship investments.

Federal Estate Tax

■ An average of 87,000 transfers of forest estates occurs each year, nationwide. Some 59 million acres of forest land are transferred each year.

■ Forest owners are many times more likely than the U.S. population in general to incur the Federal estate tax. Nationwide, about 2.6 million acres of forest land must be harvested and 1.4 million acres must be sold each year to pay the Federal estate tax.

■ Roughly one-fourth of forest acres sold to pay the Federal estate tax are converted to other, more developed uses.

Cost-Share Programs

■ Federal cost-share programs that provide funding for reforestation and management practices on private forest land include the Forestry Incentive Program, the Conservation Reserve Program, the Wetlands Reserve Program, the Stewardship Incentives Program, the Environmental Quality Incentives Program, and the Wildlife Habitat Incentives Program.

■ Funding for reforestation and timber stand improvement projects are available through State cost-share programs in 8 of the 13 Southern States: Alabama, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Programs also have been enacted in Oklahoma and Georgia but have not been funded to date. Florida implemented two programs in past years, but these have been discontinued.

■ State cost-share programs contributed payments of about $6 million for tree planting and timber stand improvement projects on about 140,000 acres in 1993. In 2000, accomplishments were nearly double, with cost-share payments of about $13.5 million for projects on about 278,000 acres. Cost-share payments and project acres in 2000 increased over 1993 levels in all seven States with programs in both surveyed years.

■ In 2000, about 87 percent of cost-share projects in Southern States were accomplished in Virginia, Mississippi, North Carolina, and Louisiana.

■ In addition to the regeneration and stand improvement assistance programs, Kentucky, North Carolina, Tennessee, and Virginia share costs for water-quality protection practices.

Current-Use Property Valuation

■ In Southern States, forest is among the classes of land eligible for current-use assessment.

■ Use-value laws, by themselves, have only a minor impact on land use decisions. It appears that use-value taxation may, at best, delay but not prevent development of rural land.

Conservation Easements

■ Over the past two decades, conservation easements have emerged as a popular tool for preserving open space and keeping land in forest cover.

■ By 1996, conservation easements on an estimated 333,000 acres of forest land had been granted to private land trusts in the Southern United States. While still influencing a relatively small portion of the region, growth in acquired acreage has been accelerating in the 1990s.

Protective Regulatory Policies

■ Most protective regulatory statutes apply to Federal and State land.

■ Few of the protective regulatory policies are specifically directed at managing private forests. In the vast majority of cases, forestry is affected only when certain activities are deemed to have the potential to impair water quality, air quality, or critical habitat for endangered species.

■ Most forestry operations are exempted from the permit requirements of Federal and State nonpoint-source pollution programs. Although provisions exist to encourage operators to meet voluntary best management practices (BMPs) and to bring polluters into compliance, these rely more heavily on education and technical assistance and less on fines and penalties.

- In the majority of instances, implementation and enforcement duties for Federal protective regulatory statutes have been delegated to the States.
- While meeting their environmental objectives, protective regulatory policies reduce overall production and raise unit costs for people who are raising timber crops.

Local Ordinances

- As of 2000, county and municipal governments in 10 of the 13 Southern States had enacted a total of 346 forest-related ordinances. This is a marked increase from 7 States and 141 ordinances in 1992.
- Most of the ordinances were enacted in States experiencing rapid urban expansion. Georgia and Virginia together account for over one-half of the total; Louisiana and Florida together account for an additional one-fourth.
- Regionwide, public property protection ordinances account for nearly half of all ordinances. Next most common are special feature protection ordinances, followed by tree protection ordinances, timber harvesting ordinances, and general environmental protection ordinances.

Private Property Rights and Right-to-Practice Acts

- Comprehensive property rights protection laws were enacted in 1995 in Florida, Texas, and Virginia, and were proposed but failed to be enacted in Alabama, Arkansas, North Carolina, and South Carolina. These laws: (1) assert landowners' constitutional rights for ownership and use of their land, (2) provide for landowner compensation for regulatory takings, and/or (3) require economic impact assessments of potentially restrictive proposed legislation or ordinances.
- Private property rights protection laws specific to forest and farmland were enacted in Mississippi in 1994 and Louisiana in 1995. These laws: (1) assert landowners' rights to conduct farm and forestry practices; (2) create a legal remedy for takings at a threshold of 20 percent of value reduction in Louisiana and 40 percent in Mississippi; and (3) in Louisiana, require an economic assessment of proposed laws for takings impact.
- Right to farm and practice forestry laws were enacted in Florida, Georgia, Kentucky, Mississippi, North Carolina, Oklahoma, South Carolina, and Virginia from 1991 through 2000. These laws: (1) recognize the benefits of forestry to the economy and ecology of the State, (2) provide protection from public and private nuisance actions against landowners conducting forestry operations, and/or (3) limit local governments' power to enact ordinances and zoning regulations restrictive to forestry.
- Right to prescribe burn laws were enacted in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, and Virginia between 1990 and 1999. These laws: (1) recognize prescribed burning as a legal and ecologically beneficial operation, (2) establish burner training/certification programs, (3) protect landowners from nuisance claims for prescribed burning activity, and (4) limit burners' liability for damages and injuries.

Introduction

This chapter addresses an extremely broad question. Southern forests and their management are influenced by a large body of legislation that stems from all levels of government: Federal, State, and local. Some laws address forests specifically, but many others influence forest conditions indirectly. Measuring the impact of a particular law or regulation can be difficult, if not impossible, except for programs that provide funding for specific actions and have reporting requirements. To a large extent, current forest conditions and trends reflect the combined impacts of all legislation in effect over time.

The topics included in this chapter address concerns identified by the public as important aspects of the overall question. Shown below are the major components of this overall question, the sections which address them, and the authors principally responsible for those sections:

a. The implications of the tax code on the structure and management of forests. This item is addressed in the sections concerning Federal income tax incentives and the Federal estate tax, authored by John L. Greene.

b. The impacts of programs that are designed to encourage forest management. This item is addressed in the section on Federal and State cost-share programs, authored by Terry Haines and John L. Greene.

c. The effects of programs for keeping land in forest cover. This item is addressed in the sections concerning current-use property valuation, authored by Brian A. Doherty, and the section on conservation easements, authored by James E. Granskog, Steven Bick, and Harry L. Haney, Jr.

d. State laws and local regulations that define landowner responsibilities in managing forests. This item is addressed by the section covering protective regulatory policies, authored by Steverson O. Moffat and Jerry Speir; the section on local forest-related ordinances, authored by Jonathan J. Spink, Harry L. Haney, Jr., and John L. Greene; and the section on private property rights and right to practice forestry acts in the South, authored by Terry Haines.

Federal Income Tax Incentives

Introduction

The Federal income tax dates from 1913, shortly after ratification of the 16th amendment to the U.S. Constitution empowered Congress to tax income "from whatever source derived" (Graetz 1997). In general, the provisions of the Internal Revenue Code (IRC) apply to private forest owners just as they do to other taxpayers. Over time, however, provisions have been added to encourage improved management of private forests:

- Depletion deductions—which recognize that part of the price owners receive from the sale of a natural resource is a recovery of their investment in the resource rather than taxable income—were first specifically applied to timber in the Revenue Act of 1919 (Siegel 1978).

- Capital gain tax treatment was originally available only to owners who sold their timber "lump-sum." The Revenue Act of 1943 extended capital gain treatment to owners who dispose of their timber "with an economic interest retained," either by selling it on a per-unit basis or harvesting it themselves and selling logs or wood products (Siegel 1978).
- Federal cost-share programs help forest owners afford the high up-front cost of investments in forest management and stewardship. Programs currently available include the Forestry Incentive Program, the Conservation Reserve Program, the Wetlands Reserve Program, the Stewardship Incentives Program, the Environmental Quality Incentives Program, and the Wildlife Habitat Incentives Program. The programs themselves are not income tax provisions, since 1979 IRC Section 126 permits forest owners to exclude a calculated part of qualifying cost-share payments from their gross income (Haney and others 2001).
- Reforestation incentives—a 10-percent tax credit on and amortization over 8 tax years of up to $10,000 of reforestation expenses per year—were enacted in Public Law 96-451 of 1980 (Haney and others 2001). The effect of these provisions is to reduce or eliminate the need for forest owners to capitalize reforestation expenses over the life of a stand.

Nevertheless, forest owners and policymakers alike continue to argue that additional incentives are needed to encourage improved management and stewardship of NIPFs. In studies conducted in 1997 and 2000, the Forest Law and Economics Research Unit of the USDA Forest Service, Southern Research Station, analyzed the economic effect of several incentives that have been proposed, including:

- income averaging;
- reducing the tax rates for long-term capital gains;
- enhancing the amortization provisions for reforestation expenses;
- permitting deduction of reforestation expenses in the year they occur;
- establishing Green Accounts, in which forest owners can accumulate pretax dollars to pay upcoming reforestation or management expenses; and
- stewardship investment provisions for qualified conservation-related investments in forest management.

Methods

A series of computer spreadsheets was developed to determine the effect of the proposed incentives on Federal tax receipts and cash flow to "typical" NIPF owners. The hypothetical owners were assumed to be a married couple who (1) own 100 acres of forest land, (2) file joint tax returns, (3) have $40,000 of other income and $6,900 in other deductions annually, and (4) have no dependent children. The $40,000 income level closely approximates the median household income for noncorporate private forest owners in the United States (Personal communication. 1997. T.W. Birch, USDA Forest Service, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073). We assumed no dependent children because over half of private forest owners are at or near retirement age (Haney and Siegel 1993, Sampson and DeCoster 1997).

The spreadsheets were constructed around management plans developed for each of the three major southern timber types: loblolly pine, bottomland hardwood, and upland hardwood. The plans specified practices and rotation lengths representative of those used by nonindustrial forest owners in the region. The plans did not, therefore, optimize financial return or fiber production, but used fundamental practices to maintain a relatively high timber growth rate over a sawtimber rotation.

The personal exemptions and rate schedules used to calculate the Federal income tax were for the 1997 tax year. The $6,900 amount used for other deductions equaled the Federal 1997 standard deduction for a married couple filing jointly. State and local taxes were included in the analysis because they affect both cash flow to the owners and Federal taxable income; the rates used were typical for a Southern State (Greene 1995).

No increases were assumed for costs, returns, or tax rates. Both the owners' personal discount rate and the interest rate earned by Green Accounts were assumed to be 4 percent after inflation.

Data Sources

Management costs for the loblolly pine timber type were taken from the "Forest Farmer 30th Manual Edition" (DuBois and others 1995) and adjusted to reflect a small ownership. Pine sawtimber and pulpwood stumpage prices were 1995 regional average prices for the Southern United States as reported in "Timber Mart-South" (Norris 1995). The management plan was developed using the COMPUTE_MERCHLOB growth-and-yield model (Busby and others 1990). The costs, returns, and management plan for the bottomland hardwood timber type were adapted from Amacher and others' (1997) findings for Nuttall oak. The costs, returns, and management plan for the central Appalachian hardwood timber type were provided by G.W. Miller (Personal Communication, 1997. G.W. Miller, USDA Forest Service, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073).

Results

Income averaging—The form of income averaging analyzed would permit forest owners to treat income from a commercial thinning or timber harvest as if it were paid in three equal annual installments, beginning in the year of the sale. The tax schedule for long-term capital gains has two tiers: (1) amounts in the bottom tax bracket (for 1997, amounts up to $41,200 minus the owners' taxable ordinary income) are taxed at 10 percent, and (2) additional amounts are taxed at 20 percent. Under income averaging, this calculation is made in each of the 3 years to which timber sale income is attributed, so that three times as much income qualifies to be taxed at the lower rate. Because the incentive alters the owners' adjusted gross income for each year over which income is averaged, State income tax also is affected. Income averaging would provide a modest benefit to owners in each of the three timber types (table 8.1) (Greene 1998).

Table 8.1—Comparison of Federal income tax incentives by timber type

Incentives	Loblolly pine	Bottomland hardwood	Upland hardwood
	Timber type		
	- - - - - - - - - *Dollars* - - - - - - - - -		
A. Current law			
Present value of Federal income tax receipts	11,202	8,669	4,774
Present value of cash flow to the owners	48,410	28,079	18,873
B. Further reduced tax rates for long-term capital gains			
Present value of Federal income tax receipts	6,502	4,953	2,382
Difference from current law	-4,699	-3,716	-2,392
Present value of cash flow to the owners	53,110	31,795	21,265
Difference from current law	4,699	3,716	2,392
C. Income averaging			
Present value of Federal income tax receipts	9,267	7,687	3,836
Difference from current law	-1,935	-982	-938
Present value of cash flow to the owners	50,557	29,214	19,911
Difference from current law	2,147	1,135	1,039
D. Enhanced reforestation amortization provisions			
Present value of Federal income tax receipts	10,077	7,180	4,736
Difference from current law	-1,125	-1,490	-38
Present value of cash flow to the owners	49,943	30,202	18,926
Difference from current law	1,533	2,123	53
E. Immediate deduction of reforestation expenses			
Present value of Federal income tax receipts	10,838	8,074	5,016
Difference from current law	-363	-595	242
Present value of cash flow to the owners	49,340	29,380	18,848
Difference from current law	930	1,301	-24
F. Green account			
Present value of Federal income tax receipts	9,881	7,151	4,774
Difference from current law	-1,321	-1,518	0
Present value of cash flow to the owners	50,181	30,196	18,873
Difference from current law	1,771	2,117	0
G. Stewardship investment provisions			
Present value of Federal income tax receipts	10,052	7,560	3,756
Difference from current law	-1,150	-1,109	-1,018
Present value of cash flow to the owners	48,410	28,079	18,873
Difference from current law	0	0	0

Source: Sections A through F—Greene 1998; section G—Greene and Beauvais (2002).

Reducing the tax rates for long-term capital gains—The 1997 Taxpayer Relief Act reintroduced the concept of preferential treatment for long-term capital investments and reduced Federal tax rates for long-term capital gains. The incentive analyzed would lower the rates further, to half those for ordinary income. Such an adjustment to Federal tax rates has no effect on State taxable income or tax due. Reducing the tax rates for long-term capital gains would provide a substantial benefit to owners in all three timber types (table 8.1), with the entire cost borne at the Federal level (Greene 1998).

Enhancing the amortization provisions for reforestation expenses—The incentive analyzed would further reduce the need for forest owners to capitalize the high up-front cost of investments in forest management by doubling the amount of reforestation expenses that can be amortized (from $10,000 to $20,000) and compressing the recovery period from 8 to 6 tax years. The reforestation tax credit—10 percent of the first $10,000 of qualifying expenses—was assumed to be unchanged. The incentive would provide the greatest benefit to owners with reforestation expenses above the $10,000 amount that can be amortized under current law. Such cost levels are typical for loblolly pine and bottomland hardwood management. Owners with reforestation expenses under $10,000 would derive a small benefit from the shortened recovery period (table 8.1) (Greene 1998).

Permitting deduction of reforestation expenses—Permitting forest owners to deduct reforestation expenses as they occur would eliminate the need to capitalize any of the high up-front costs associated with forest management. Reforestation expenses would be on a par with property taxes, interest, and forest management expenses, which can be deducted in the year they occur. This incentive would provide a modest benefit to owners whose reforestation expenses are above the $10,000 amount that can be amortized under current law. It would not benefit owners whose reforestation expenses already can be fully amortized (table 8.1) (Greene 1998).

Establishing Green Accounts—Two types of Green Accounts were analyzed: one modeled after a traditional IRA, and the other modeled after the cafeteria-plan Medical Saving Accounts available to many taxpayers through their employers. Either type of account would enable forest owners to pay reforestation costs that cannot be amortized with pretax dollars, eliminating the need to capitalize them. For this reason, benefits from this incentive follow the same pattern as for deduction of reforestation expenses, except they are larger because reforestation expenses are paid with pretax dollars. Again, the incentive would provide no benefit to owners whose reforestation expenses already can be fully amortized under current law (table 8.1) (Greene 1998).

Stewardship investment tax provisions—An increasing number of NIPF owners hold and manage their land primarily to produce social or environmental benefits (Birch 1996). The IRC, however, provides favored tax treatment only to owners who manage their forests to produce marketable products or services. Expanding four provisions of the IRC would afford the same tax treatment to all owners who receive cost-share assistance from qualified Federal or State programs to actively manage their forests, whether they manage for environmental or social benefits, or for profit:

- that all owners who receive qualified cost-share assistance to establish or reestablish trees may take the reforestation tax credit as permitted under IRC Section 48 and amortize their out-of-pocket expenses from the practice, as permitted under Section 194;
- that all owners who receive qualified cost-share assistance to establish trees may exclude from their gross income the full amount of the payment permitted under Section 126;
- that all owners who receive qualified cost-share assistance to carry out forest management practices may deduct their out-of-pocket expenses for the practices, as permitted under Section 212; and
- that all owners who receive qualified cost-share assistance to establish or manage trees may deduct the full amount of their basis in trees lost in a casualty, condemnation, or theft, as permitted under Section 165.

In each case, owners who could demonstrate that they did not have a profit motive would qualify for the provision on the basis of having made an approved stewardship investment. These provisions would afford little additional cash flow to the owners, since many of the cost-share practices will not yield marketable products (table 8.1) (Greene and Beauvais 2002). But they would benefit owners in all three timber types by reducing the cost of making environmentally beneficial stewardship investments.

Discussion and Conclusions

The first and second incentives alter the amount of Federal income tax due from a timber sale. A reduction in the tax rates for long-term capital gains would provide a substantial benefit to forest owners in all three timber types. Because it is a general provision that applies to all types of businesses and investments; however, the reduction would cause a large decrease in Federal tax receipts. Income averaging over 3 years would yield a more modest, targeted benefit to owners in all three timber types. The additional cash flow these incentives provide would enable nonindustrial forest owners to improve the level of management and stewardship. But the incentives would be available to all owners who sell timber, whether or not they manage their forest.

The third, fourth, and fifth incentives alter the tax treatment of reforestation expenses. All three incentives would benefit owners with reforestation expenses above the $10,000 amount that can be amortized under current law. The financial benefit provided by enhanced amortization provisions or a Green Account would be larger, and that provided by deduction of reforestation expenses in the year they occur smaller. Enhanced amortization provisions also would provide a small benefit to owners with reforestation expenses that can be fully amortized. These incentives are specifically tied to reforestation of harvested areas. For this reason, they have the potential to promote changes in owners' management behavior and improve the overall level of management and stewardship on NIPFs.

The final incentive would extend provisions already present in the Federal tax code to an additional class of owners: those who manage their forest primarily for environmental or social purposes. The incentive would provide owners little or no economic benefit, but would encourage and enable owners in all timber types to make environmentally beneficial stewardship investments.

Ideally, components of a Federal tax policy to improve NIPF management would be politically acceptable, cause minimal reductions in tax receipts, require no fundamental changes to the tax code, specifically target private forests, benefit owners in all timber types, and be tied to forest management. Of the incentives analyzed, only enhanced amortization provisions for reforestation expenses might satisfy all of these criteria. But four additional incentives: (1) income averaging, (2) deduction of reforestation expenses in the year they occur, (3) Green Accounts, and (4) stewardship investment provisions meet enough of the criteria that they also merit consideration.

Needs for Additional Research

Fundamental research is needed to assess landowner use of the incentives for improved forest management and stewardship that are already present in the Federal tax code. There also will be a continuing need to analyze the effects of incentives proposed since the studies summarized here were conducted. To date, these include an inflation adjustment for timber capital gains and a partial capital gain exclusion. An additional class of incentives that might be developed would encourage forest owners to work in concert to develop and pursue management plans on a landscape scale. Such incentives would address the issues of urban sprawl, forest fragmentation, wildlife habitat requirements, and biodiversity.

The Federal Estate Tax

Introduction

The Federal Government has taxed the transfer of estates from one generation to another since 1916 (Haney and Siegel 1993). To prevent most estates from being affected by the tax, gifts up to $10,000 per recipient per year, plus other lifetime gifts and estate values below the amount shielded by the unified credit effective exemption are not taxed. In recent years, however, the number and percent of estates that owe Federal estate tax have increased markedly (Herman 2001).

To address this situation, the newly enacted Economic Growth and Tax Relief Reconciliation Act of 2001 increases the unified credit effective exemption from $675,000 to $1 million beginning in 2002, and gradually reduces the top rate for Federal estate and gift taxes from 55 to 45 percent by 2009. The Act eliminates the estate tax entirely and sets the top tax rate for gifts equal to the top individual income tax rate beginning in 2010. But the Act itself is scheduled to "sunset" at the end of 2010, returning estate and gift taxes to prior law (Manning and Windish 2001).

There are reasons to believe the Federal estate tax has a greater effect on forested estates than on estates in general. Increasing stumpage prices (Morrow and Fritschi 1997) and urban expansion (Harris and DeForest 1994, U.S. Department of Commerce 1992) are driving up the value of both the timber and land components of forest

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land. Further, the requirements for special use valuation, a provision that permits rural land to be assessed for estate tax purposes at its value in use rather than its highest and best use, are difficult to meet, particularly for managed forests.

Beyond anecdotal evidence, however, little information is available on the effect of the estate tax. A handful of case studies used hypothetical families and forest holdings to investigate aspects of the transfer of forest estates, including: (1) the size of a forest that can be transferred without incurring a tax (Sutherland 1978), (2) the effect of the estate tax on returns to forest management (Sutherland and Tedder 1979), (3) the effect of using special use valuation on the net value of a forest estate (Gardner and others 1984), and (4) the interaction between Federal and State estate and inheritance taxes (Peters and others 1998, Walden and others 1987). In addition, Howard (1985) studied the effect of form of forest ownership and assets used to pay the estate tax on returns from the forest, and two studies have examined the effect of the estate tax on transfers of large forest holdings (Lucas 1963, Northern Forest Lands Council 1994).

The Mississippi State University, College of Forest Resources, and the Forest Law and Economics Research Unit of the USDA Forest Service, Southern Research Station, are cooperating in a study to gauge the effect of the Federal estate tax on nonindustrial forests and other rural land holdings. It is the first attempt to quantify the effect of the Federal estate tax on rural land.

Methods

Data for the study were collected by means of a mailed questionnaire, using the Dillman (1978) Total Design Method. The questionnaire was pretested with a 100-percent survey of members of the Mississippi Forestry Association. Following the pretest, randomly selected members of two national forest owner groups—the American Tree Farm System and the National Woodland Owners Association—were surveyed.

This report summarizes key findings from the two national samples and contrasts them to the results from Mississippi, which is assumed to be a representative Southern State.

Response Rates

The combined response rate for the two national forest owner groups was 46 percent. Although most members of both groups are NIPF owners, their responses to questions regarding location of the land, form of ownership, and value of the gross taxable estate differed statistically from one another. Stratifying the responses by region accounted for these differences. The response rate for Mississippi Forestry Association members was 66 percent.

Results

National forest owner groups— Eighty-three percent of the survey respondents from the national samples were members of the deceased owner's family. Nine percent were involved in the transfer of a forest estate during the 11 years prior to 1998, a period when the applicable credit shielded $600,000 of estate value from the Federal estate tax.

Seventy-nine percent of the deceased owners held their forest in fee simple or jointly with a family member. Sixty-three percent had used the services of a financial or legal professional to plan their estate; in 60 percent of the cases, their heirs believed that using a professional reduced the estate tax due.

Only 33 percent of the estates qualified for and 25 percent applied special use valuation. In 74 percent of the cases when special use valuation was used, it was applied to both the land and timber. The value of the estate typically was reduced to an amount well below the $750,000 maximum for the provision.

Thirty-six percent of the estates owed Federal estate tax. In 44 percent of the cases where Federal estate tax was due, timber or land was sold to pay part or all of the tax. Some 75 percent of timber sales and 57 percent of the land sales occurred because other estate assets were inadequate to pay the tax. The size of forest estates in which timber or land had to be sold to pay the estate tax ranged from under 100 acres to several thousand acres, averaging over 500 acres.

Mississippi Forestry Association— The results of the survey of Mississippi Forestry Association members differed from those of the national forest owner groups in several respects. A larger fraction of the respondents in Mississippi (14 percent) were involved in the transfer of an estate during the survey period, and a smaller fraction of the deceased owners (43 percent) had used the services of a professional in planning their estates.

Eight percent of the estates in the Mississippi survey qualified for and only 5 percent made use of special use valuation. In just 27 percent of the cases where Federal estate tax was due, land or timber was sold to pay part or all of the tax. Eighty-nine percent of the sales, however, occurred because other estate assets were inadequate to pay the tax. Of the acres of land sold, 67 percent was converted to other, more developed uses.

Discussion and Conclusions

The effect of the Federal estate tax on forest estates can be estimated on a national basis by applying the number of private forest ownership units from Birch (1996) to the survey findings. It should be noted that many of the resulting estimates are based on small samples and should be considered rough indicators rather than scientific estimates.

From the calculation, it appears that an average of 87,000 transfers of forest estates occur each year, nationwide. The amount of forest land transferred is estimated at 59 million acres per year.

It appears that about 19,000 forest estates per year make use of special use valuation. Typically, the procedure is applied to both land and timber. In many instances, this may be necessary to meet the requirements for use of the provision, but doing so precludes harvesting of timber for 10 years.

Forest owners are much more likely than the U.S. population in general to incur the Federal estate tax. The amount of forest land that must be harvested each year to pay the tax appears to be on the order of 2.6 million acres, and the amount of forest land that must be sold each year to pay the Federal estate tax appears to be on the order of 1.4 million acres. Of the acres of land sold, it appears that roughly one-fourth is converted to other, more developed uses.

To the extent that Mississippi is representative of the region, a smaller fraction of forest estates in the South may qualify for or make use of special use valuation than in other

Table 8.2—Features and accomplishments of State forestry cost-share programs

State programs	Cost-share rate	Maximum payment	Site productivity ranking	Ownership limits	Project limits
	Percent	*Dollars*		- - - - - - - - - - *Acres*	- - - - - - - - -
Alabama Agricultural and Conservation Development Program	60	3,500/yr	No	20 min.	1 min.
Louisiana Forest Productivity Program	50	10,000/yr	No	None	None
Mississippi Forest Resources Development Program	50-75	5,000/yr	No	None	None
North Carolina Forest Development Program	40-60	None	No	None	1 min. to 100 max.
South Carolina Forest Renewal Act	40	None	Yes	None	100 max.
Tennessee Reforestation Incentives	50	5,000/yr	Yes[1]	None	None
Texas Reforestation Foundation Program	50	None	Yes	1,000 max.	10 min.
Virginia Reforestation Timberlands Act	40	75/ac	No	None	1-5 min. and 500 max.

yr = year; min. = minimum; max. = maximum; ac = acre.
[1] erodible lands.

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U.S. regions. Also, in the cases where Federal estate tax is due, a smaller fraction of estates in the South may sell timber or land to pay part or all of the tax. It appears, however, that a larger fraction of the acres sold is converted to other, more developed uses.

Needs for Additional Research

The study summarized here presents several avenues for development of a coordinated estate tax relief policy for forest owners, but additional work is needed to address its statistical shortcomings by obtaining a larger and broader sample of NIPF owners.

Acknowledgments

Other persons involved in the study were Tamara Cushing, F&W Forestry Services, Inc., Albany, GA; Steve Bullard, Professor of Forest Economics, Mississippi State University, College of Forest Resources, Mississippi State, MS; and Ted Beauvais, Natural Resources Planning Specialist, USDA Forest Service, Cooperative Forestry, Washington, DC. At the time the surveys were conducted Ms. Cushing was a graduate research assistant at Mississippi State University, College of Forest Resources.

Federal and State Forestry Cost-Share Programs

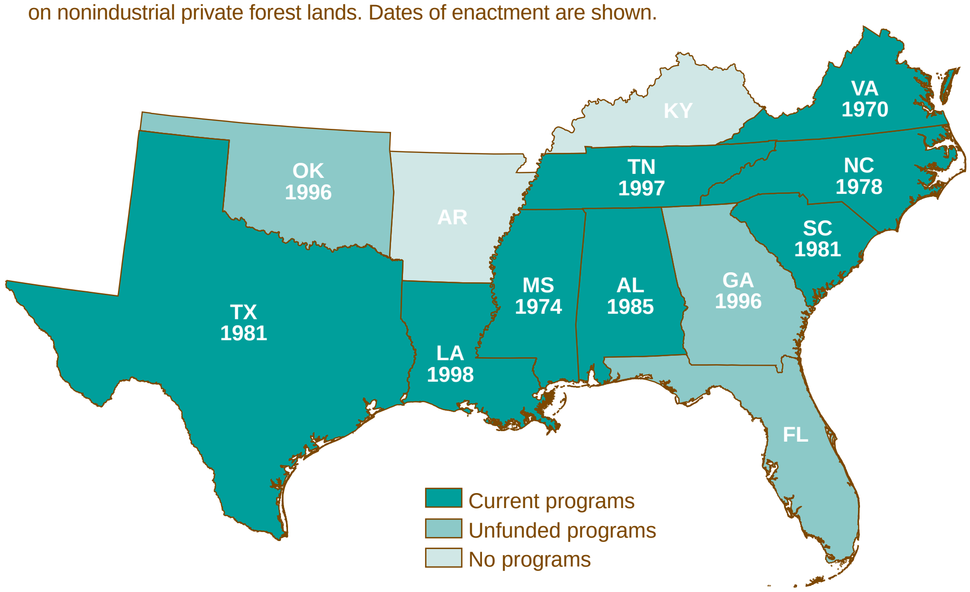
Introduction

Nonindustrial private forest landowners play a vital role in sustaining forest resources. In 1997, NIPF land provided about 50 percent of the softwood harvest and 75 percent of hardwood harvest nationwide (Haynes, in press). As timber harvests from Federal land have been reduced in recent years, the supply of timber from NIPF land has become more crucial.

Two important barriers to NIPF landowner investments to optimize forest productivity are the lack of up-front capital and low expected rates of return. Cost-share programs are designed to help NIPF landowners by reducing their initial costs for reforestation and improving rates of return.

Federal cost-share funding was insufficient to meet the needs of NIPF landowners in many Southern States. Several Southern States, therefore, established forestry cost-share programs in the 1970s and 1980s (tables 8.2 and 8.3). Funding for these programs increased more than 60 percent between 1981 and 1985 (Bullard and

Figure 8.1—State level cost-sharing programs to improve timber production on nonindustrial private forest lands. Dates of enactment are shown.



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Straka 1988). Two States, Louisiana and Tennessee, implemented programs in the late 1990s.

The largest State programs in terms of payments and acreage treated are in the South. Southern States with programs include Alabama, Louisiana, Florida, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia (fig. 8.1). Outside the South, as of 1994, cost-share assistance programs for timber production had been established only in California, Illinois, Iowa, Maryland, Minnesota, and Oregon (Haines 1995).

Methods and Data Sources

Haines (1995) comprehensively reviewed Federal and State cost-share programs. For the present Assessment, therefore, the need was for updating that work. To do so, information about Federal cost-share programs was collected from the Internet sites of the U.S. Department of Agriculture (USDA) agencies that administer each of the six programs. Data on State programs were obtained by sending a questionnaire to officials in each of the 13 Southern States. Officials were queried about any changes in their State's cost-share programs since 1994 and for information about any programs enacted since 1994. Topics covered in the questionnaire included: (1) landowner eligibility requirements and limitations, (2) cost-share rates, (3) eligible management practices, (4) funding sources and annual level of funding, (5) annual cost-share payments, (6) project acres accomplished, and (7) outlook for continuation or expansion of the program.

All but 2 of the 13 State officials contacted completed the questionnaire. Through phone contacts with officials in the two nonreporting States, the necessary information was obtained.

Table 8.3—Funding and accomplishments of State forestry cost-share programs

State program and date implemented	Source of funding	Annual cost-share payments for reforestation and timber stand improvement	Annual accomplishments, reforestation, and timber stand improve.	Trends in funding
		Dollars	*Acres*	
Alabama Agricultural and Conservation Development Program, 1985	General State fund	750,000	21,300	Slightly increasing
Louisiana Forest Productivity Program, 1998	Timber severance tax	4,100,000	50,000	Variable with severance tax receipts
Mississippi Forest Resources Development Program, 1974	Timber harvest tax	3,000,000	63,588	Variable
North Carolina Forest Development Program, 1978	Timber harvest tax and State general funds	2,200,000	52,000	Increasing
South Carolina Forest Renewal Act, 1981	Timber harvest tax and State general funds	657,438	6,494	Stable
Tennessee Reforestation Incentives Program, 1997	Real estate transfer receipts	160,000	2,500	Variable with real estate market
Texas Reforestation Foundation Program, 1981	Voluntary forest industry assessment on primary products	350,000	7,000	Stable
Virginia Reforestation Timberlands Act, 1970	State general funds and harvest tax	2,253,546	75,900	Stable

Results

The State agency responses to the questionnaire and information from Federal program Internet sites were compiled and summarized to describe features and accomplishments for each program.

Federal cost-share assistance programs—Federal cost-share assistance programs for forestry projects include the Forestry Incentive Program, the Conservation Reserve Program, the Wetlands Reserve Program, the Stewardship Incentives Program, the Environmental Quality Incentives Program, and the Wildlife Habitat Incentives Program.

Forestry Incentive Program (FIP)—FIP was established by the Cooperative Forestry Assistance Act of 1978 to encourage timber production and the use of good forest management practices on NIPF land. It shares costs for practices associated with tree planting, timber stand improvement, and site preparation for natural regeneration. To be enrolled, land must be suitable for afforestation, reforestation, or improved forest management and be located in a county identified by the USDA Forest Service as suitable for growing timber products. Participants generally must own between 10 and 1,000 acres of eligible land (exceptions for up to 5,000 acres can be authorized) and cannot be engaged primarily in manufacturing forest products or providing public utility services.

State forestry agencies have the lead role in implementing FIP. The agencies help participants develop forest management plans and, if necessary, help them find vendors to perform practices called for in the plans. Some agencies have arranged for some or all management plan development work to be done by consulting foresters. The agencies also must certify that practices are completed satisfactorily before cost-share payments can be made. Payments are limited to $10,000 per participant per year and are not to exceed 65 percent of the cost of practices performed.

FIP is administered by the USDA Forest Service and the Natural Resources Conservation Service (NRCS) in cooperation with the State Foresters. Fiscal year (FY) 1997 funding for the program was $6.3 million.

Conservation Reserve Program (CRP)—CRP was established by the 1985 Food Security Act to convert highly erodible cropland and other environmentally sensitive land to protective vegetative cover. It shares costs for establishing long-term resource-conserving cover, land rental payments under 10- to 15-year contracts, and incentive payments to encourage wetland restoration or use of continuous sign-up provisions. To be enrolled in CRP, land must be cropland that is defined as erodible or associated with noncropped wetlands or marginal pastureland that is suitable for use as a riparian buffer. Applicants generally must have owned or operated the land for at least 12 months; new owners must have inherited the land, acquired it as the result of a foreclosure, or be able to show that they did not acquire the land for the purpose of placing it in CRP.

Applicants offer bids for CRP contracts, which are ranked and selected for funding based on the Environmental Benefits Index (EBI). The EBI rates the relative environmental benefits of land according to several factors, including wildlife habitat, water, and air quality benefits; on-farm benefits of reduced erosion; probable long-term benefits; and cost. Establishing a tree cover consistently rates at or near the top of the EBI scale. Payments are limited to 50 percent of the cost of practices performed, with an incentive of an additional 25 percent available for practices to restore wetlands. Land rental payments are based on the relative productivity of soils in the county, with an incentive of 10 to 20 percent available to encourage landowners who implement specific environmentally related practices to take advantage of continuous sign-up provisions. CRP is administered by the Farm Service Administration (FSA). FY 1997 funding was $200 million for cost-shares, land rental payments, and incentives.

Wetlands Reserve Program (WRP)—This program also was established by the 1985 Food Security Act to restore lost or degraded wetland habitat on private land. It operates by purchasing permanent or 30-year conservation easements on qualifying wetlands, or by providing cost-share assistance under agreements lasting 10 years or more. To be enrolled, land must be privately owned, restorable, and suitable for wildlife benefit. Wetland converted after December 23, 1985, land with timber stands established under a CRP contract, and land where restoration is not possible are excluded from the program. Participants must have owned the land for at least 1 year or be able to show that they did not acquire the land for the purpose of placing it in WRP.

The NRCS assists participants to develop plans to restore their wetland. Participants agree to limit future development of their land, but retain ownership, control over access, the right to lease the land for undeveloped recreation, and, with approval, the right to use it for activities compatible with WRP, such as grazing, cutting hay, or harvesting timber. There are defined limits on the amount that can be paid for a conservation easement; the USDA pays all restoration costs under a permanent easement and 75 percent of restoration costs under a 30-year easement. Payments under a cost-share agreement cannot exceed 75 percent of the cost of practices performed.

WRP is administered by the NRCS in cooperation with FSA. Funding for the program in FY 1997 was $76 million.

Stewardship Incentives Program (SIP)—This program was established by the 1990 Farm Bill to encourage multiple resource management on NIPF land. It provides technical and cost-share assistance to implement practices called for in a Forest Stewardship Plan. To be enrolled, land must be rural and forested or suitable for growing trees. Participants can be any type of legal private entity, including an individual, group, association, corporation, or American Indian tribe. They generally must own no more than 1,000 acres of eligible land, although exceptions for up to 5,000 acres can be authorized.

The State forestry agency helps participants develop Forest Stewardship Plans. Participants agree to maintain their land as described in their plan and to maintain and protect SIP-funded practices for at least 10 years. SIP cost shares can help pay for a variety of forest management activities, including development of the Forest Stewardship Plan; reforestation and afforestation; forest and agroforest improvement; establishment, maintenance, and improvement of hedgerows; protection

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and improvement of soil, water, riparian areas, or wetlands; and enhancement of fisheries habitat, wildlife habitat, or recreation. Payments are limited to $10,000 per participant per year and cannot exceed 75 percent of the cost of practices performed.

SIP is administered by the USDA Forest Service in cooperation with the State forestry agencies. Funding in FY 1997 was $6.5 million. The program has not been funded for the past 3 fiscal years.

Environmental Quality Incentives Program (EQIP)—EQIP was established by the 1996 Farm Bill to assist farm and ranch owners in addressing natural resource problems that pose a significant threat to soil, water, or related resources. It provides technical help and cost-share assistance under 5- to 10-year contracts to enable owners to implement practices called for in a conservation plan, and incentive payments for up to 3 years to encourage adoption of desired land management practices. To participate in EQIP, land must be farm or ranch land and applicants must be engaged in livestock or agricultural production. Owners of large confined livestock operations—generally over 1,000 animal units—cannot receive cost-share assistance for animal waste storage or treatment facilities, but they can receive assistance for other conservation practices.

The NRCS assists applicants to develop site-specific conservation plans that address locally identified natural resource concerns. At designated times during the year, plans are ranked and selected according to their potential environmental benefit weighed against their cost. Priority is given to practices where State or local governments provide technical or financial assistance, and to practices that will help producers comply with Federal or State environmental laws. Cost-share payments cannot exceed 75 percent of the cost of practices performed; cost-share and incentive payments combined are limited to $10,000 per participant per year or $50,000 over the life of a contract.

EQIP combines and replaces four earlier Federal assistance programs: (1) the Agricultural Conservation Program, (2) the Water Quality Incentives Program, (3) the Great Plains Conservation Program, and (4) the Colorado River Basin Salinity Control Program. The program is administered by the NRCS in cooperation with FSA. Funding was $200 million in FY 1997.

Wildlife Habitat Incentives Program (WHIP)—This program also was established by the 1996 Farm Bill to encourage development and improvement of wildlife habitat on private land. It provides technical and cost-share assistance under 5- to 10-year agreements to implement practices associated with wildlife habitat improvement. Any non-Federal land can be enrolled in WHIP, unless it is enrolled in another conservation program, it is subject to an Emergency Watershed Protection Program floodplain easement, or success with habitat improvement efforts is unlikely. Participants must own or control the land under consideration.

The NRCS assists participants to develop wildlife habitat development plans. Participants agree to install and maintain the practices called for in their plan and to allow NRCS access to monitor effectiveness. Cost-share payments cannot exceed 75 percent of the cost of the practices performed, and generally are $5,000 or less per participant per year.

WHIP is administered by the NRCS. A multi-year appropriation passed in FY 1997 averaged approximately $8 million per year.

State forestry cost-share assistance program—Funding for reforestation and timber stand improvement projects are available through State cost-share programs in 8 of the 13 Southern States: Alabama, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. State-level programs also have been enacted in Oklahoma and Georgia but have not been funded to date. Florida has implemented programs in past years, but they have been discontinued. In addition to the reforestation and stand improvement assistance programs, four States—Kentucky, North Carolina, Tennessee, and Virginia—have implemented cost-share programs for water-quality protection practices.

Alabama cost-share program—The Alabama Agricultural and Conservation Development Commission Program was enacted in 1985, in response to cutbacks in funding for Federal conservation and reforestation cost-share programs. The program is administered by the Alabama Agriculture and Conservation Commission. The Alabama Forestry Commission provides technical support for forestry practices. Funding is provided through State general funds. Eligible land includes private, State, and other non-Federal public holdings of 20 acres or more, with a minimum treatment area of 1 acre. Approved forestry practices include tree planting, site preparation, natural regeneration, timber stand improvement, prescribed burning, permanent fire line construction, and some soil and water-quality protection practices. The cost-share rate is up to 60 percent, with a maximum payment of $3,500 per year. Most practices must be maintained for 10 years; 5 years of maintenance are required for timber stand improvement. Practice priorities are determined by the local soil and water conservation districts.

In 2000, disbursements totaling $750,000 were made for reforestation and timber stand improvements on about 20,000 acres—more than double the 1994 disbursement of $349,000. Small increases in future funding are anticipated.

Florida cost-share program—No State-level cost-share programs are currently available in Florida, and none are anticipated in the near future. As a result of USDA Forest Service inventory reports indicating overcutting of baldcypress in Florida's panhandle region, the Federal FIP program has been restructured to give highest priority to landowner projects for cypress plantings.

The Florida Reforestation Incentives Program was established through a joint agreement between the Florida Division of Forestry and the Florida Forestry Association in 1981 to encourage reforestation on private land by providing reimbursement for seedling costs. The program was discontinued in 1993 due to budget cuts at the division of forestry and the resulting closure of all but one State tree nursery.

The Florida Plant a Tree Trust Fund Program, which was established in 1991 to increase urban tree planting and rural reforestation and was administered by the Florida Division of Forestry, has also been discontinued. Funding began in 1995 with a contribution of $70,000 from the Sunshine Gas Pipeline Company, a natural gas transmission company utilizing rights-of-way in the State. Eligible applicants included local governments, nonprofit organizations, and private landowners owning or controlling parcels of at least 10 and no more than 1,000 acres.

Kentucky cost-share program— The Kentucky Soil and Water Quality Cost-Share Program was initiated in 1994 to promote agricultural conservation practices. Initial funding of $500,000 was provided through an increase in the State pesticide registration fee. In 2000, legislative appropriations of $2,150,000 from general funds and $9 million from tobacco settlement funds provided a total of $11,150,000 for the program. Practices are prioritized, and funds are allocated to the conservation districts accordingly. Currently, agricultural waste control practices are given highest priority. Approved forestry projects are generally for installation of BMPs. Twenty applicants requested a total of $64,379 in cost-share funds for forestry practices during 2000. Nine of the projects were funded for a total of $29,025.

Louisiana cost-share program— The Louisiana Forest Productivity Program was initiated in 1998 in response to concerns about possible shortages in future timber supplies. The program provides financial assistance to landowners for the establishment and improvement of tree crops. Funding is provided through a portion of the State's timber severance tax. To be eligible for the program, landowners must own a minimum of 5 contiguous acres suitable for growing commercially valuable timber species; no maximum ownership size limits participation. Landowners may receive 50 percent of the cost of reforestation and timber stand improvement for stand release up to $10,000 per year. Landowners must develop a management plan and maintain the forestry usage for 10 years. In 2001, $4,100,000 was disbursed for cost sharing on 50,000 treated acres. Annual program funding varies with harvest levels and severance tax rates.

Mississippi cost-share program— The Mississippi Forest Resource Development Program was authorized in 1974 in response to concerns about the future availability of softwood timber. The program is financed through 80 percent of timber severance tax collections and is administered by the Mississippi Forestry Commission. Assistance is available on a first-come, first-served basis to NIPF and non-Federal public landowners. No minimum ownership acreage or treatment area is stipulated. Landowners are required to submit a management prescription for the desired treatment area, comply with commission standards during operations, and maintain practices for 10 years.

The cost-share rate is 50 percent for tree planting, site preparation, prescribed burning, firebreak construction, and timber stand improvement. The rate is 75 percent for direct-seeding and mixed-stand regeneration. Payments are limited to a total of $5,000 per landowner per year.

Disbursements for cost-share payments have increased from $1,829,608 in 1994 to about $3 million in 2000. Funding levels are variable from year to year, depending on timber harvest revenues. Annual treatments increased from about 39,000 acres in 1994 to more than 63,500 acres in 2000.

North Carolina cost-share program— The North Carolina Forest Development Program was implemented in 1978 to increase productivity of private forests in the State while protecting soil, air, and water resources. The program is available to industrial (including forest industries) as well as nonindustrial owners. Funding is provided through a combination of State general funds of $700,000 per year and revenues of about $1.5 million annually from a tax assessed on primary forest products.

A forest management plan with provisions for assuring forest productivity and environmental protection must be approved by the division of forest resources. Approved practices on a minimum of 1 acre include site preparation, silvicultural clearcutting, tree planting or seeding, and release treatments to ensure the survival of the stand.

The cost-share rate is 40 percent for most practices. In 1993, however, a rate of 60 percent was offered for planting hardwoods and longleaf pine and for planting wetland species such as baldcypress and Atlantic white-cedar. There has been substantial interest and response to the incentive to plant longleaf pine.

Program eligibility limitations are: (1) landowners are restricted to a maximum of 100 acres each year, (2) projects must be initiated within 1 year and completed within 2 years after funding approval, and (3) practices must be maintained for 10 years as prescribed in the approved management plan. In addition, projects not conducted in accordance with State BMPs may not be funded and may be subject to penalties under the State's Sedimentation and Pollution Control Law.

Program accomplishments include assistance to 22,666 landowners for tree planting on more than 766,000 acres between 1978 and 1999. In 2000, about 2,000 landowners received assistance for treatments on 52,000 acres. Some 38,441 acres were treated in 1994.

The North Carolina Agricultural Cost-Share Program for Non-Point Source Pollution Control was established in 1985 to encourage conservation practices, including tree planting, on erodible soils where water quality is being impaired. The program is administered by the North Carolina Department of Environment, Health, and Natural Resources, Division of Soil and Water Conservation, and is funded through State general appropriations. The cost-share rate for tree planting is 75 percent of the average cost of establishing fescue up to a maximum of $15,000 per year. In 1999, 646 acres were planted in trees under the program.

A temporary program, the Fran Reforestation and Rehabilitation Program, was established in 1997 to assist private landowners with reforestation and stand rehabilitation from damages resulting from Hurricane Fran (September 1996). An allocation of $4,100,000 from the Governor's Disaster Relief Reserve funded the program. Cost-share rates ranged from 40 to 60 percent of the cost of stand establishment and improvement practices.

South Carolina cost-share program— The South Carolina Forest Renewal Act was enacted in 1981 to provide incentive payments to private landowners to increase the productivity of their forest land and to ensure a continuing and adequate flow of wood products in the State. At that time, some 2 million acres of poorly stocked or idle nonindustrial private land were in need of reforestation (Izlar 1983).

The act directs the South Carolina Forestry Commission to administer the program and to ensure that forest operations are conducted in a manner that protects the State's soil, air, and water resources.

The program is funded through a combination of State appropriations (20 percent) and a severance tax (80 percent) on primary forest products. From the program's inception in 1981 through 1995, the General Assembly appropriated $100,000 annually, and the forest industry tax provided four times that amount for a total outlay of $500,000 per year. However, in 1996, the General Assembly increased its appropriation to $200,000, and the industry severance tax provided $800,000 for a total outlay of $1 million per year. Funding in the future is expected to remain at this level.

All private nonindustrial land capable of producing at least 50 cubic feet of industrial wood per acre per year is eligible for cost-share assistance. The program requires a minimum treatment area of 10 acres for mechanical site preparation; otherwise, there are no minimum acreage limitations. A forest management plan must be approved by the forestry commission, and the project area must be maintained in a forest condition for at least 10 years.

Approved practices include natural and artificial regeneration, timber stand improvement, and prescribed burning. The average cost-share rate is 40 percent, with reimbursements limited to the amount needed to complete the project on 100 acres. For artificial regeneration, the program requires that all merchantable timber be removed before applications are accepted. Disbursements of $657,438 were made to landowners in 1999 for practices on 6,494 acres. The totals in 1994 were $515,736 for treatments on 5,904 acres.

Tennessee cost-share program— The Tennessee Reforestation Incentives Program was initiated in 1997 to provide financial assistance to landowners for planting trees on marginal and highly erodible cropland and pastureland. Cost-share payments are available to plant pine trees and control competing vegetation. The Tennessee Division of Forestry administers the program. Funding is provided by the State Agricultural Resources Conservation fund, which was established with a portion of Tennessee's real estate transfer tax receipts. The cost-share rate is 50 percent of costs. Since 1997, total cost-share payments have ranged from $140,000 to $180,000 per year for treatments on 2,000 to 3,000 acres. Annual payments are limited to $5,000 per landowner per year.

The Agricultural Resources Conservation Program, which prior to 1998 was known as the Agricultural Nonpoint Source Pollution Program, was initiated in 1993. It provides cost-share assistance for soil and water improvement and riparian zone protection practices on private agricultural land, including non-industrial forest land. Costs are shared for forestry practices, including application of BMPs on harvested sites and bottomland hardwood plantings. The program was administered by the State Department of Agriculture through the county soil conservation districts until 1998, when administration was transferred to the division of forestry. Technical support for forestry projects is also provided by the Tennessee Division of Forestry.

The program was initially funded in part by a 3-year grant from the U.S. Environmental Protection Agency (EPA). Continued funding has been from the State Agricultural Resources Conservation fund, which was established with a portion of Tennessee's real estate transfer tax receipts. Funding levels vary with fluctuations in the real estate market.

Annual cost-share payments range from $14,000 to $20,000 per year for forestry projects. A stewardship plan, modeled after the Federal stewardship program plan, is required. The cost-share rate is 75 percent for BMP application and riparian zone protection and 50 percent for bottomland hardwood plantings. Annual cost-share payments are limited to $5,000 per landowner.

Texas cost-share program— The Texas Reforestation Foundation Program was chartered and funded in 1981 by forest products companies in an effort to increase the productivity of private nonindustrial woodlands and thereby ensure future timber supplies. The program is administered by the Texas Forestry Association. Technical assistance is provided by the Texas Forest Service. To apply for funds, a landowner must submit a forest management plan for projects located in the commercial forestry region of east Texas. The cost-share rate is 50 percent for land clearing, site preparation, tree planting, and release treatments on 10 or more acres. Applicants are prioritized according to tract size, previous cover, and site index; higher ranking is assigned for small ownerships, cutover land, and properties with high site indices. The program requires practices to be maintained for 10 years.

All major forest products companies, as well as several smaller companies, provide financial support through a voluntary assessment on primary forest products. Funding is relatively stable at about $400,000 per year. Cost-share disbursements were $350,000 in 2000 for reforestation on about 7,000 acres. In 1994, cost-share payments of $280,839 were made for reforestation and timber stand improvement on 6,096 acres. Funding has not been sufficient to meet landowners' demands; in most years over $1 million is requested for projects.

Virginia cost-share program— The Virginia Reforestation of Timberlands Act was established in 1970 to maintain a viable pine industry in light of 1966 USDA Forest Service forest inventory statistics indicating softwood removals exceeding growth by 15 percent (Marcum 1993). The program is administered by the Virginia Department of Forestry and is financed through an assessment on primary forest products and matching State funds. Funding from the industry tax was $800,000 initially, increased to about $1 million in 1994, and was $1,274,000 in 2000. Matching State funds have not been fully appropriated in all years due to budgetary constraints, but in 2000, State general funds of $1,313,574 were appropriated.

All private landowners, including industrial forest landowners, are eligible for the program. Reimbursements are available for 40 percent of the cost of site preparation, tree planting, and brush control in pine stands up to a maximum of $75 per acre. However, land requiring reforestation under the State seed tree law is not eligible for this program, except where more than 75 percent of the stand is infested by the southern pine bark beetle. The minimum project size is 5 acres, unless planting is done without site preparation, in which case the minimum is 1 acre. The maximum project size is 500 acres. The program requires the use of BMPs within project boundaries and a 10-year commitment to maintain practices.

In 1994, disbursements of $1,014,331 in cost-share payments were made for reforestation and timber stand improvement on 40,393 acres. In 2000, payments more than doubled to $2,253,546 for practices on 75,900 acres. Funding is expected to remain stable.

The Virginia Agricultural Best Management Practices Cost-Share Program was established in 1984 as part of a multi-State effort to protect water quality in the Chesapeake Bay watershed. The development of a stewardship plan and compliance with BMPs are encouraged, but not mandatory. The program offers a $150-per-acre payment for tree planting on erodible cropland or pastureland in addition to cost-share payments from other programs. Cost-share assistance is also available for stabilizing abandoned logging roads and planting streamside buffer strips. The program is administered by the soil and water conservation districts. Funding for the program includes Federal outlays, State revenues, and contributions from private organizations, such as the Alliance for the Chesapeake Bay. Funding for forestry practices has been around $50,000 annually.

Discussion and Conclusions

Softwood harvest on NIPF land is projected to increase from 5.2 billion cubic feet in 1997 to 7.2 billion cubic feet by 2050 in response to reduced harvests on national forest and other Federal land (Haynes, in press). Most of the increase in supply is projected to come from pine plantations in the South. If these plantations are not established, timber availability could be a problem in some areas.

The long-term nature of forestry investments, coupled with the up-front capital required to establish regeneration and perceived low rates of return, are major disincentives to some NIPF landowners. Cost-share payments partially offset landowners' initial costs for site preparation, tree planting, and forest stand improvement and increase profits at harvest.

Most State cost-share assistance programs are patterned after the Federal FIP, ACP, or SIP. However, specific program features vary greatly among the States.

Program funding is generally from State revenues, most commonly from timber harvest taxes and general State appropriations (table 8.3). A variety of private sources has contributed to funding of several States' programs. The Texas cost-share program is unique in that it is funded entirely by a voluntary, self-assessed tax on forest industry firms. The Virginia Agricultural Best Management Practices Cost-Share Program is funded in part by contributions from a private organization, the Alliance for the Chesapeake Bay.

Definitions of eligibility vary among the States but generally include one or more of the following criteria: (1) minimum or maximum ownership or project size limitations, (2) site productivity ranking, and (3) priority ranking of projects according to State resource goals (table 8.2). All programs focus primarily on NIPF land, but other ownerships are eligible in some States. Corporate and industrial forests are eligible for cost sharing in North Carolina, South Carolina, and Virginia. The South Carolina program specifically excludes wood-processing industries; in contrast, the North Carolina and Virginia programs include forest industries as eligible ownerships. Non-Federal public land is also eligible in Alabama and Mississippi.

Eligible forestry practices generally include tree planting, site preparation for natural and artificial regeneration, timber stand improvements, and prescribed burning. Other activities that may be eligible include management plan development, soil and water-quality protection practices, and fish and wildlife habitat improvement.

Maximum cost-share payment rates in 2000 ranged from 40 percent in North Carolina and Virginia to 75 percent for direct-seeding and mixed stand regeneration in Mississippi. Most commonly, rates are 50 to 60 percent. All State programs require landowners to develop a management plan and require that practices be retained for 10 years (table 8.2). None of the Southern State programs permit landowners to receive concurrent Federal and State cost-share assistance for the same project.

The tax treatment of cost-share payments has been favorable for landowners. Under Section 126 of the IRC, all or a part of cost-share payments for reforestation and some other practices may be excludable from the landowner's taxable income (Hoover 1989).

Cost-share payments from Federal programs that have been approved for exclusion for Federal income tax purposes include FIP, SIP, WRP, EQIP, and WHIP. To date, CRP cost-share payments have not been ruled excludable. Cost-share payments from the following State programs have been approved for exclusion: (1) the Louisiana Forest Productivity Program, (2) the Mississippi Forest Resource Program, (3) the North Carolina Forest Development Program, (4) the South Carolina Forest Renewal Act Program, and (5) the Virginia Reforestation of Timberlands Act Program.

The Southwide accomplishments of State cost-share assistance programs for tree planting and timber stand improvement were about 140,000 acres in 1994. In 2000, treatments nearly doubled to 278,000 acres. In 1993, the leading State programs were in Virginia, Mississippi, and North Carolina where 40,393, 39,254, and 38,441 acres, respectively, were treated. Projects in these three States represented about 90 percent of the acreage treated in the South and about 83 percent of the acreage treated nationwide with State cost-share funding (Haines 1995).

In 2000, the leading State programs were again in Virginia, Mississippi, and North Carolina, in addition to the newly implemented program in Louisiana. Treated acres were 75,900, 63,588, 52,000, and 50,000, respectively. These totals represent about 87 percent of the 278,000 acres of cost-share accomplishments across the South in 2000 (table 8.3).

Assistance for forest land management that does not include timber production as a primary goal has expanded greatly over the past 15 years. Awareness of the importance of nontimber forest resources, especially water quality and wetlands, has increased markedly. In the South, State cost-share programs for soil and water conservation and riparian zone protection have been established in Kentucky, North Carolina, Tennessee, and Virginia.

The efficiency of cost-share programs might possibly be improved by lowering cost-share rates, particularly in times of increasing stumpage prices. In this way, more owners and more acres might be covered with the same expenditures. In addition, discontinuing some Federal programs and redirecting Federal dollars to State cost-share programs could decrease administrative costs. In 1996, Federal funding of $750,000 was appropriated to the Texas cost-share program.

In addition to cost-share programs, potential policy mechanisms to improve forest productivity and expand the forest land base include mandatory reforestation regulations or a mixture of incentive programs with regulatory mandates. For example, minimum reforestation standards might be required on harvested sites, and cost-share payments might be offered only for tree planting on open land. Additional afforestation opportunities include tree planting to offset environmental degradation such as that from pollutants emitted by coal-fired plants or to sequester carbon from other sources (Moulton 1994).

State-level tax incentive programs to promote forestry have been implemented in some Southern States. Mississippi offers a State income tax credit for reforestation costs. Oklahoma and Texas have exempted products used for forestry purposes from sales tax. Another incentive in Texas is the retention of the agricultural property tax assessment for 15 years after trees are planted on former agricultural land. Previously, the tax rate escalated upon planting of seedlings.

In recent years, State tax incentive programs have been initiated specifically to preserve, improve, and create wetlands and riparian zones. Reduced property tax assessments are available in Oklahoma for riparian buffer strips and in Texas for riparian buffer strips and endangered species habitat. State income tax credits are offered in Arkansas for the costs of establishing and maintaining wetlands and riparian zones. In Virginia, a tax credit is available for 25 percent of the value of the timber retained in riparian buffers, up to $17,500.

Future Research Needs

Comprehensive analysis of the various cost-share, tax incentive, and technical assistance programs is needed to determine the most effective policy options in terms of forestry investments, individual landowners' goals, forest sustainability, and future benefits for society overall.

Finally, there is a need to compare the cumulative effects of an individual State's institutional mechanisms: tax policies, cost-share programs, and regulatory programs on forestry investments and forest resource protection.

Acknowledgments

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Current-Use Property Valuation

Introduction

Current-use property tax laws provide that properties be assessed and taxed based on their productivity or income-producing potential in their current use, if that use is considered socially desirable. Forestry and agriculture are such uses. Current-use laws were enacted in response to criticisms of the traditional ad valorem tax. All 13 Southern States have use-value laws that include forests among the classes of land eligible for current-use assessment. Nationwide, 42 States have 47 use-value laws that include forests among the eligible land classes.

Under these laws, land is assessed and taxed solely on the basis of its income-producing potential when used for forestry purposes. In practice, however, significant differences exist among the statutes as to how forest land use values are to be determined. This section briefly reviews the use-value laws applicable to forest land in the South, examines the differences in procedures to determine assessed value, and looks at the impacts of such laws.

Methods

When the United States was founded, the States retained the right to establish their own property tax systems. Thus, considerable variation exists among State systems for taxing forest property. The USDA Forest Service sponsored several reviews of State forest land and timber tax laws (Carlen 1976; Nelson 1941; Williams 1956, 1967). These studies mostly examined the existence and depth of coverage of State assessment guides for forest land and timber. The Timber Tax Journal provided a yearly update of forestry property tax laws until it ceased publication in 1984. Hickman (1982, 1983) summarized State current-use property tax laws in several publications. The summaries were updated in 1993 (Doherty 1993). At that time, the State statute books were searched to identify States with use-value laws that include forests among the classes of land eligible for current-use assessment. Property tax officials in each of these States were contacted and asked to provide administrative rules and regulations, assessment guides, and other relevant published materials that supplement and clarify the statutory provisions. The statutes and the information obtained were used to summarize procedures for each State. The summaries were then returned to the property tax officials in each State so that the accuracy of the information contained therein could be verified.

For this Assessment the summaries were again updated by searching for changes in the statutes and by using the State property tax summaries available on the National Timber Tax Web site (Department of Forestry and Natural Resources, Purdue University 2001). The updated summaries were used to identify and categorize restrictions, requirements, and alternative procedures.

Results

Reasons for enactment—Assessment and taxation of forests on the basis of use value emerged in the 1960s as a way of slowing the conversion of rural land to more intensive uses, such as industrialization, first- and second-home construction, and recreation development. Forest landowners were often forced to develop their land because its market value commonly exceeded values based upon current income-producing ability. Use-value laws were seen as a way of restoring the balance between a property's taxable value and its income-producing potential. Hickman (1982) reported that use-value laws were seen as achieving two closely related goals:

1. Owners of forest, farm, and other rural land who wanted to profitably keep their properties in their traditional uses could do so; and

2. The State and its citizens would reap the benefits derived from the continued management of the rural land base.

Between 1950 and 1970, conversion of forest land was a serious problem in certain parts of the United States. Modest losses were experienced in the South, but the total acreage remained essentially unchanged. Losses of privately owned farmland were much more pervasive and substantial, however, declining 14 percent (Wall 1981). Such losses were of great concern for two reasons: (1) losses to development are essentially irreversible; and (2) a multitude of economic, social, and environmental benefits are derived from rural uses. Examples of these benefits include: (1) greater assurance of sufficient food and fiber to meet future needs; (2) the economic activity generated by viable agricultural and forest industries; (3) increased outdoor recreation opportunities for urban and suburban residents; (4) protection, or perhaps even improvement, of air and water quality; and (5) a slowing of urban sprawl.

Key forestry provisions—Use-value laws are of three basic types: (1) pure preferential assessment, (2) deferred taxation, and (3) restrictive agreements. Each provides for assessment and taxation of qualified properties based on current-use value as opposed to market value based on highest and best use. The differences between the three types stem from two things: (1) the restrictions placed on the ability of participating property owners to change land use, and (2) the provisions contained for recouping the tax concessions granted to participating property owners when they convert their properties to some ineligible use.

Under pure preferential assessment, land withdrawn from the program or converted to an ineligible use is subsequently taxed on the basis of fair market value, but no declassification penalty is imposed. Under deferred taxation, eligible land that is withdrawn from the program or converted to another use not only is taxed at highest and best use but is subject to a penalty based on the taxes saved during the period of classification. Finally, under restrictive agreements, the owners of eligible land contract with the State to restrict the use of their property for a specified number of years. In return, they are granted current-use assessment. During the period of the contract, changes in land use are usually permitted only if they are deemed to be in the public interest. When development is allowed, a penalty based on the taxes saved during the period of classification is generally imposed.

Five Southern States have pure preferential assessment statutes, seven have deferred taxation statutes, and one, Georgia, has a restrictive agreement statute (table 8.4).

Three of the southern statutes are mandatory, and 10 are optional. In States with mandatory laws, all forest land that is eligible for use-value assessment must be assessed and taxed on the basis of its worth for forestry purposes.

All use-value laws essentially have the same structure. Their key provisions generally coincide with the law's chief administrative steps. The administration of a use-value property tax statute usually involves (1) setting the conditions for eligibility; (2) evaluating applications (if necessary) for enrollment; (3) assigning a dollar value to the enrolled property; (4) overseeing continued enrollment, withdrawal, and related penalties; (5) providing a review or appeal process concerning eligibility and assessment; and (6) collecting and distributing the taxes. See Hickman (1982, 1983) and the Gulf South Research Institute (1982) for more details.

Valuation methodology—The asset that is to be assessed and taxed differs among the statutes, and this difference has some bearing on the selection of a valuation method. In some States, both the land and timber thereon are considered taxable property under annual ad valorem taxation. In several other States, however, the use-value law is linked with an exemption statute, wherein standing timber is exempt from annual ad valorem property taxation but is usually taxed instead at the time of harvest through a yield tax or severance tax. Thus, care must be taken to ensure that the valuation methodology is appropriate for the asset to be valued. Standing timber is statutorily exempt from annual property taxation in Alabama (Code of Alabama, 40-7-25.1 to 40-8-1), Georgia (Code of Georgia Ann., 48-5-2, 48-5-7.4, and 48-5-269), Louisiana (Louisiana Rev. Stat., 47:2301 to 47:2309), Mississippi (Mississippi Code, 27-35-49 to 27-35-50), North Carolina (North Carolina Gen. Stat., 105-277.2 to 105-277.7, 105-289, and 105-360), and Tennessee (Tennessee Code Ann., 67-5-1001 to 67-5-1011). Virginia statutes do not exempt standing timber from property taxation, but they tax the value of the bare land alone.

In most Southern States the chief State administrative agency or advisory committee publishes schedules of recommended current-use values, which may be broken down by region, forest type, and productivity class across the State. In these cases, the local (generally county) assessors select from the range of values provided in the tables, making adjustments, if applicable, using personal knowledge, judgment, experience, and other information that may be available. In other States, however, the tax department or an advisory committee develops procedures, usually detailed in an assessment guide, for county assessors to use in valuing individual properties. County assessors in these States use procedures and data provided by the chief administrative agency and apply them to develop assessed values for either individual properties or productivity classes in their counties.

Kentucky (Kentucky Rev. Stat., Sec. 132.450) is unique among Southern States in that it simply lists the factors to be considered in determining use value and leaves it up to the assessor to determine their relevance. The factors to be considered include: (1) the income potential of principal crops; (2) prices of comparable land acquired for agricultural purposes; (3) relative percentages of tillable land, pastureland, and woodland; (4)

Table 8.4—State and year use-value law enacted

	State and year												
Key forestry provisions	AL 78	AR 81	FL 59	GA 91	KY 70	LA 76	MS 80	NC 73	OK 74	SC 75	TN 76	TX 79	VA 71
Type of statute													
1. Pure preferential assessment		X	X			X	X		X				
2. Deferred taxation	X				X			X		X	X	X	X
3. Restrictive agreements				X									
Scope of statute													
1. Mandatory		X					X		X				
2. Optional	X		X	X	X	X		X		X	X	X	X
Restrictions on eligibility													
1. None, i.e., all forest land eligible	X	X							X				
2. Minimum acreage				X	X	X	X	X			X		X
3. History of forest use				X								X	
4. Under approval/sound program of management								X			X		
5. Minimum annual gross forest income						X							
6. Areas classified/zoned as forest land			X										X
7. Timber available for harvesting												X	X
8. Market value exceeds use value								X					
9. Highest and best use is timber growing													
10. Other				X				X		X		X	X
Application requirements													
1. None		X							X				
2. Initial application	X			X	X			X		X	X	X	X
3. Annual applications or recommitments			X				X						
4. Enter contractual agreement													
5. Other				X		X							
Determination of current use value													
1. Definition only													
2. Relevant factors listed					X								
3. Agriculturally based valuation									X		X		
4. Income capitalization	X	X	X	X		X	X	X	X	X	X	X	X
a. Schedule provided	X			X			X	X		X	X	X	X
b. Timber exemption	X			X		X	X	X			X		
c. Bare land value approach								X					X
d. Sustained yield approach	X	X	X	X		X	X		X	X	X	X	
5. Other				X						X			
Declassification penalty													
1. None		X	X			X	X		X				
2. Rollback tax	X			X	X					X	X		
3. Rollback tax with interest								X				X	X

soil productivity; (5) risk of flooding; (6) land improvements relating to production of income; (7) accessibility to all-weather roads and markets; and (8) all other factors affecting the general agricultural or horticultural economy—interest rates, product prices, input costs, etc.

The value of forest land has traditionally been determined under one of three bases: (1) cost methods for restoring a forestry investment, (2) comparison of sales of similar forested properties, and (3) capitalization of expected timber income (Williams and Canham 1972). The first of these—the use of historical, replacement, or restoration costs—is of limited value in determining the current-use value of forest land. First, past costs may be out of line with current costs because of appreciation or depreciation, present or prospective changes in use, or costs that were out of line to begin with. Second, immediate replacement or restoration is physically impossible because of the time element necessary to grow another stand. Timber cannot be directly replaced, and it is impossible to replace an uneven-aged stand (Williams and Canham 1972). Only Florida's law lists the cost-replacement approach as one of the choices, along with the market and income capitalization approaches, that the assessor may choose in valuing forest land (Rules of the Florida Department of Revenue, Division of Ad Valorem Tax, Chapter 12D-51.01). However, the statute recommends the income-capitalization approach, stating that the cost-replacement approach is not suited for measuring the ability of land to generate income from the growing of timber.

The second possible basis for valuing forest land is a market analysis of sales prices of similar forested properties. The advantage in using market value is that it integrates all the relevant factors comprising value. The market analysis approach is much more commonly used if highest and best use is the valuation criterion. With current use for growing timber as the criterion, however, the sales transactions in the analysis must be properties in which timber management is the highest and best use or for which the land is limited to timber management use. Problems arise in using this approach when an alternative use of a property, such as a motel site, significantly alters its value. Another difficulty in using this approach is that no two properties are exactly alike, and it is difficult to find enough transactions involving similar properties.

While none of the statutes base use value solely on a comparison of sales of comparable properties, several use this methodology at least in part. The use-value statutes of Kentucky (Kentucky Rev. Stat., Sec. 132.450) and Tennessee (Tennessee Code Ann., 67-5-1008) list the prices of comparable land acquired for agricultural or forestry purposes as one of the relevant factors to be considered in determining use value. Florida includes market sales analysis among the three different approaches that assessors may choose from in estimating use value. The Georgia State Revenue Commissioner bases the annual recommended use-value schedule on a weighted combination of sales data and capitalized net income (Georgia Code Ann., 48-5-269). Sales data for comparable real property with and for the same existing use represent 35 percent of the weighted value. In South Carolina, an index of the average value per acre of farm real estate land and buildings is used to construct a multiplier to adjust the base-year fair market value for land used to grow timber. The multiplier is determined using an income capitalization method (South Carolina Code, 12-43-220). Outside the South several States use stumpage prices as well as land sales data as part of a hybrid approach, often in combination with income capitalization.

The final and most widely used basis for determining forest-use value is the capitalization of expected income from the land. In States where forestry is a major land use, expected income is synonymous with the expected future earnings from timber management. Under this approach, forest-use value is equal to the discounted net present value of the stream of anticipated future income accruing to the land from timber production.

Some States consider value from nontimber uses in their formulas for capitalizing expected income. Florida's statute allows for income from naval stores and range pasture usage to be considered along with timber income (Rules of the Florida Department of Revenue, Division of Ad Valorem Tax, Chapter 12D-51.01). In Texas, land on which timber harvesting is restricted to meet aesthetic, conservation, water protection, or plant or animal pro-tection goals may qualify for appraisal as restricted-use timberland (Sec. 23.9801, Tax Code). Land in an aesthetic management zone, critical wildlife habitat zone, or streamside management zone is appraised at one-half of what it would have been appraised at under normal circumstances.

A variant of the income capitalization approach allows rental rates for land used for timber production to be used as a proxy for anticipated future timber income. Annual net cash rental is usually determined through an analysis of typical rental agreements collected over the years prior to the year for which the valuation is being determined. Comparable land must be used for forestry purposes and located in the vicinity, if practicable, of the property being valued. Among Southern States, only Oklahoma capitalizes timber income based on rents from land dedicated to that use.

Two main variants of income capitalization are: (1) the bare-land-value approach, and (2) the sustained-yield approach. Under the bare-land-value approach, a stand is assumed to be established on cutover land, grown to maturity, harvested, and the process repeated interminably. Bare-land value, also known as land-expectation value, is equal to the present net worth of an infinite series of periodic incomes. Forest land is regarded as the sole productive agent and timber as working capital. Under this approach, bare land is the basic asset to be valued, with standing timber exempted from taxation (Hickman 1989). Among the Southern States, only North Carolina and Virginia use the bare-land-value approach.

The sustained-yield approach involves capitalizing the net value of the mean annual growth increment, as if it occurred as an annual income, given an assumed rotation length. A fully regulated forest is assumed to exist in which an equal income is produced in the current and all subsequent years. Timber is regarded as fixed capital because it has to be in place to produce such an income pattern. The "factory" in which timber is produced consists of both land and trees (Hickman 1989, Williams and Canham 1972).

Thus, when this approach is used to determine forest-use value, timber as well as the land is taxed. This approach is used by the other 10 Southern States that use income capitalization. Several States that exempt timber from taxation nonetheless use the sustained-yield method. Despite this policy inconsistency, there is no evidence that property taxes are any higher in these States as a result.

A number of statutes have provisions that provide a floor or ceiling on assessed value. In Georgia, for example, the current-use value of any conservation-use property may not increase or decrease by more than 4 percent from its value for the previous taxable year or increase or decrease during a covenant period by more than 25 percent from the first year of the covenant period (Georgia Code Ann., 48-5-269). Similarly, Mississippi does not allow the variation in use value, up or down, from a previous year to exceed 10 percent (Mississippi Code, 27-35-49 to 27-35-50). Alabama's statute provides that assessed value may not be less than that levied in the first tax year for which values are computed, and may not be greater than the assessed value in the first tax year plus amounts equal to 3 percent of such values multiplied by the number of tax years elapsed since the first tax year (Code of Alabama, 40-7-25).

Impacts—The intent of use-value assessment of forest and other rural land is to provide property tax relief to participating landowners so that their land may continue to contribute socially desired benefits, which include food and fiber for future economic activity, open space at the urban fringe, and the slowing of urban sprawl. While States may adopt use-value assessment for any or all of these reasons, there are impacts that follow from this policy decision. As in Hickman (1983), the discussion here focuses on three main areas: (1) equity implications, (2) revenue implications, and (3) effectiveness.

■ Equity—Use valuation causes the taxes of participating property owners to decrease. Local government taxing bodies normally respond to the resulting decrease in the tax base by increasing tax (millage) rates. The taxes of nonparticipating owners rise, and they collectively share a greater proportion of the total tax burden. The magnitude of the tax shift depends on the amount by which use value reduces the assessment of participating properties and the percentage of the total base that is in participating property. The amount of taxes shifted increases as participation rises. At a certain point, the number of participating properties outstrips the ability of the remaining non-participating owners to absorb the tax shift.

■ Revenue—If local governments do not have the flexibility to increase tax rates due to legislation or political pressures, the decline in the value of the tax base due to use-value assessment can have important revenue implications. Local governments depend heavily on property taxes to fund schools and provide public services. Any portion of lost revenues not offset by an increase in the tax rate is a cost of the program.

The revenue and equity implications often receive the most scrutiny when use-value programs are implemented. Concerns are high where the enrollment rates continue to grow and the tax base continues to erode (Newman 2000). When Georgia first implemented its current-use valuation program in 1992, there was considerable concern over the erosion of the tax base. A few counties lost almost 20 percent of their taxable base (Whitt 1992). The problem was exacerbated because Georgia constitutionally removed standing timber from property taxation in 1990 and replaced it with a yield tax that taxed timber only when it was cut. In this case, the tax-shifting impacts were particularly large, but the benefits also were substantial.

■ Effectiveness—A search of the literature reveals a general agreement that use valuation provides substantial tax relief to participating owners. Most researchers, however, believe that this relief, by itself, does not retain forest and other rural land in traditional uses (Anderson 1993, Coughlin and others 1978, Ferguson and Spinelli 1998, Gloudemans 1974). It appears that use-value taxation may, at best, delay but not prevent development of rural land. The most often cited reason is that property owners may be unable to resist the large capital gains associated with development. It also is believed that the present value of the tax savings may be capitalized into higher land prices by raising the reservation prices of a significant number of landowners (Gottfried and others 1999). While use valuation plays a role in changing the relative profitability of land uses, land use change is thought to be driven by a broad range of other factors: population and migration changes, socioeconomic characteristics of landowners, and transitional factors.

Discussion and Conclusions

Loss of forest land continues to be a serious problem despite the enactment of use-value laws. The latest data show that 2.63 million acres of southern forest were developed between 1992 and 1997. This area represents 48 percent of all land developed over that period (fig. 8.2). Texas, Georgia, and Florida led the Nation in the amount of land developed during this period (U.S. Department of Agriculture, Natural Resources Conservation Service 1997). Population growth and migration drive much of this development. Among the economic, demographic, and socioeconomic factors that influence land use change (Alig and others 1998), use-value assessment, by itself, may have only a minor impact. The impact depends largely on the degree of development pressure that exists in a given county. In mostly rural counties, use-value assessment probably has little impact because there is little difference between use value and market value. By comparison, in counties with rapid development, the difference between market and use value may be so large that most landowners choose to sell their land or convert it to a higher value use. In such areas, owners must want to keep practicing forestry; that is, they must receive intangible benefits from keeping land in forest. Gottfried and others (1999) call this the "reservation premium," the monetized present value of the intangible benefits. As the present value of the income from forestry uses plus the reservation premium exceeds the market value, the probability of conversion decreases.

Much of the land enrolled under State use-value programs is far from major metropolitan areas. This land faces little or no development pressure. There should be little difference between use value and fair market value for these properties. The two may be different because States often use different procedures in determining market value as opposed to use value. There are at least two examples where the enactment of use-value laws resulted in enrolled forested properties having higher use valuations than comparable properties assigned fair market values. This situation was a result of select counties underestimating fair market values (Hickman and Gayer 1983, Krietemeyer and others 1987). The much more common circumstance is where the use valuation results in an assessed value below fair market value. Researchers (Brockett and others 1999) studying Tennessee's Greenbelt use-value statute found that it ". . . largely functioned as a windfall for participating landowners [in areas removed from development pressures] without a commensurate return for the rest of the area's citizens." The mixed objectives of the different State current-use laws make it difficult to gauge whether the benefits received justify the costs of these programs. Some statutes have stringent eligibility requirements that preclude all but land under active forest management. States with these statutes may consider the benefits flowing from actively managed forest lands as commensurate with the costs to nonparticipating landowners.

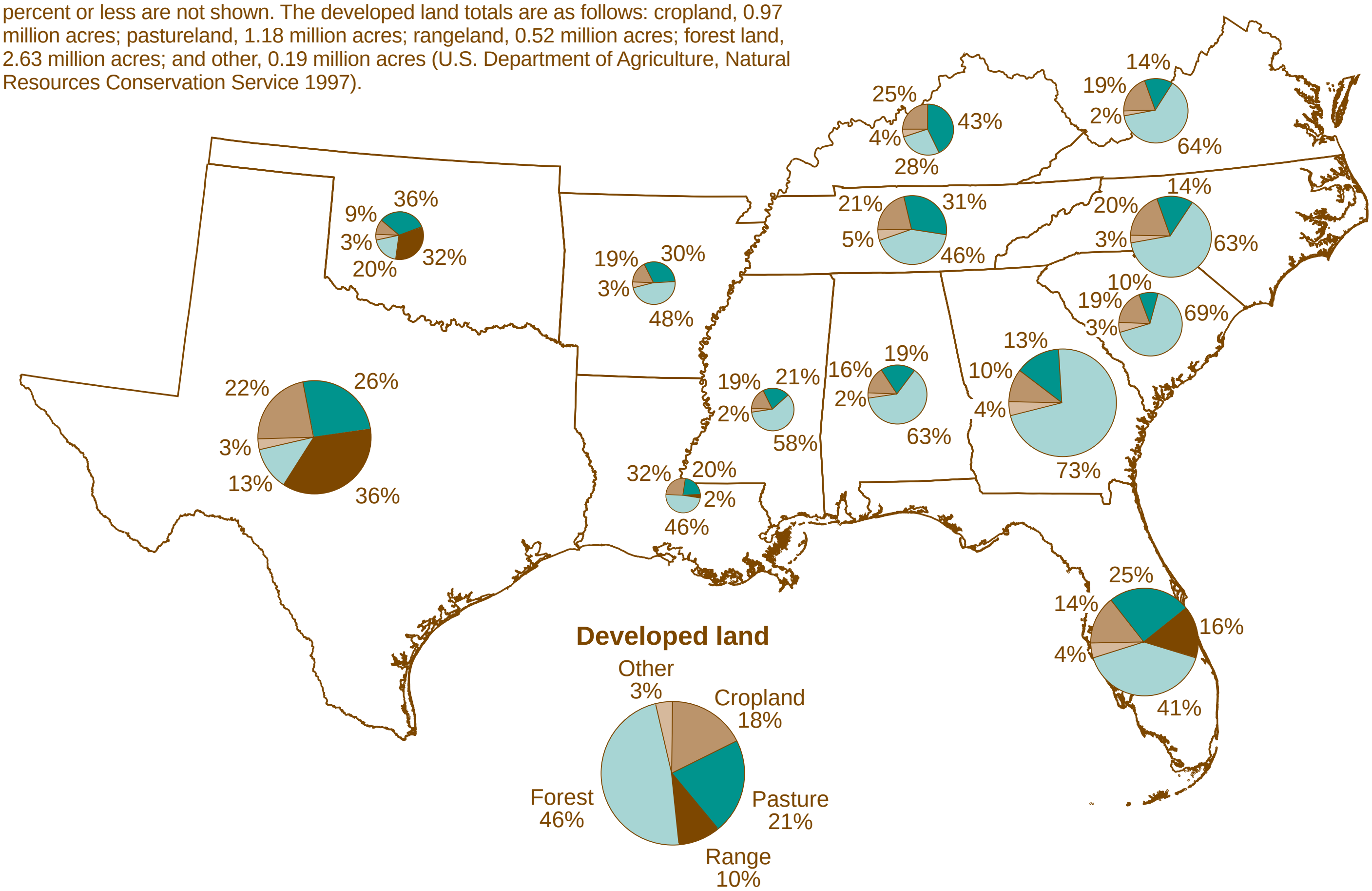
Many serious questions have been raised about the suitability of use-value legislation for retaining forest and other rural lands. In fact, some areas experiencing high rates of growth have seen no benefit from use-value programs. In Virginia, some counties have given up on tools for slowing conversion and want to assess impact fees on developed land to pay for the infrastructure and services needed to accommodate the growth (Ferguson and Spinelli 1998). States will likely keep use-value statutes, perhaps in some modified form, for two main reasons (Hickman 1983): (1) the desire to keep forest, farm, and other open space land from converting to developed uses is at least as strong today as it was when these laws were enacted; and (2) the alternatives to use valuation—rural zoning, transferable development rights, public fee simple land purchases—have their own disadvantages, some more serious than those of use valuation.

States may look at modifications to improve the efficacy of their use-value statutes. Hickman (1982) made several recommendations that are still valid today. One of these concerns the need for stringent declassification penalties. The rollback tax should recoup all tax savings plus interest for the entire period that a property receives use valuation. Hickman's principal reasoning is that it promotes taxpayer equity. He argues that nonparticipating property owners who fund the program should recoup their costs when the intended benefits are not obtained. Moreover, statutes with higher declassification penalties would discourage speculation and would be more likely to attract landowners who are serious about long-term forest use.

Needs for Additional Research

1. Changes in the relative profitability of land uses, resulting from tax policies or otherwise, do not necessarily translate into identical

Figure 8.2—Land uses converted to 5.5 million total acres of developed land, southern region, 1992-97. The pie charts are proportional to the amount of land developed. The southern region pie chart is not proportional to the State pie charts. Data values of 1 percent or less are not shown. The developed land totals are as follows: cropland, 0.97 million acres; pastureland, 1.18 million acres; rangeland, 0.52 million acres; forest land, 2.63 million acres; and other, 0.19 million acres (U.S. Department of Agriculture, Natural Resources Conservation Service 1997).



changes in land use. Studies are needed that look at the demographic and socioeconomic characteristics that are associated with the decision to convert forest or rural land to a more developed use. Such a study might look at how these characteristics are related to the owner's reservation price.

2. Forest and rural land conversions have been increasing in locations far from major metropolitan areas. The nostalgia for small-town living, the desire to live and work in beautiful surroundings, and the new telecommunications possibilities unleashed by the digital revolution have led to boomlets in parts of the mountain west, coastal Maine, and the Blue Ridge and Smoky Mountains (Kotkin and Siegel 2000). Additional research may be needed to assess the role and efficacy of use-value programs in this new wildland-urban interface.

Conservation Easements

Introduction

An easement is a partial ownership interest in a parcel of land, or the right to use the land for a special purpose. Conservation easements are legally binding agreements between private landowners and nonprofit or government agencies restricting future activities that can take place on a parcel of land. The purpose is usually to preserve the open character of the land by arresting or slowing development.

Conservation easements are becoming more popular for preserving or controlling land use by landowners and government. For landowners, a conservation easement is a voluntary land use restriction, which offers a means to reduce taxes while the land remains in its current use. On the other side, conservation easements are one part of a larger spectrum of land use controls used by various levels of government. For the latter, conservation easements may accomplish land management goals when other land use controls are either too expensive or unavailable.

The popularity of conservation easements has grown since the 1970s, when the IRC was amended to allow charitable Federal income tax deductions for qualifying conservation donations, including conservation easements (Bick and Haney 2001). However, the use of conservation easements to protect productive forest land from development and fragmentation appears to be more recent (Best and Wayburn 1996, Boelhower and Van Ryn 1996).

Methods and Data Sources

The examination of conservation easements was added to this chapter in response to public input. Time constraints precluded any new study beyond a review of recent literature. Data were obtained from a 1996 survey by Bick and others (1998) to estimate the acreage of conservation easements on forest land held by private land trusts in the South. Forest land easement deed provisions in the South were summarized from Bick and Haney (1999).

Results

Forest land acreage—The survey by Bick and others (1998) provided estimates of the growth and extent of conservation easements on forest land. The information was based on a questionnaire mailed to all organizations in the "1995 National Directory of Conservation Land Trusts" that listed conservation easements as a land protection method. One question requested the number of conservation easements and acreage on open spaces by land use types. The land use types selected were farmland, forest land, wetlands, green space, rare sites, and other.

Nationally, forest was the largest single land use among properties protected with conservation easements. Through 1996, private land trusts had acquired some 5,600 conservation easements on forest land, encumbering almost 1.6 million acres. A majority of the acreage had been acquired between 1991 and 1996. Conservation easements on an additional 900,000 acres of forest land were projected for purchase by existing land trusts by 2001.

About one-fifth of the total acreage was in the South. Northeastern States were among the leaders in terms of the number of reported forest land agreements, but Southern States were among the leaders in reported acreage, indicating a higher average protected property size in the South.

Additional data for 13 Southern States were obtained from the survey database (table 8.5). Four States—Florida, Virginia, North Carolina, and Mississippi—accounted for 97 percent of the 333,000 acres in the South; small amounts were also reported for Texas, Tennessee, and South Carolina. Other States did not have land trusts that reported forest land easements at the time of the survey. However, legislation was enacted in Alabama in 1997 that formally provided for conservation easements on real property, and data from the 1998 National Land Trust Census show land trusts have been formed in all 13 Southern States except Oklahoma (Land Trust Alliance 2000).

Deed content—As a part of the survey by Bick and others (1998), copies of conservation easement deeds were requested from land trusts for the different types of land protection. The content of the conservation easement deeds received was analyzed and divided into four distinct categories: affirmative rights, restrictions, reserved rights, and terms and conditions. Within each category, variables were identified and grouped to determine how provisions affected timber,

Table 8.5—Conservation easements on forest land granted to private land trusts in Southern States, 1996

State	Total land area	Average size
	- - - - - - - *Acres* - - - - - -	
AL	0	0
AR	0	0
FL	132,571	2,073
GA	0	0
KY	0	0
LA	0	0
MS	52,598	1,481
NC	64,973	1,407
OK	0	0
SC	1,492	105
TN	2,693	152
TX	4,913	86
VA	73,897	189
Total	333,137	—

development, and amenity values (Bick and others 1999).

The components of conservation easement deeds—affirmative rights, restrictions, reserved rights, and terms and conditions—work in unison to prevent, restrict, encourage, or guarantee certain uses of the forest and associated management practices. Affirmative rights express things the grantee (land trust) is allowed to do on or with the protected property. Restrictions limit the activities of the grantor (landowner) except for those allowed under reserved rights. Reserved rights are uses of the property retained by the grantor. Terms and conditions spell out the remaining details of the agreement, such as liability issues and division of property tax burdens.

A regional analysis provided insight into conservation easement deed contents as they related to forest values in the South (Bick and Haney 1999). For timber, restrictions tended to constrain production through limits on timber harvesting methods and bans on certain forest management practices. Reserved rights pertaining to timber focused only on the harvesting of forest products, including timber and nontimber products such as pine straw, Christmas trees, and fence posts. The only affirmative right of grantees associated with timber was the right to inspect properties for compliance. Overall, a lack of provisions pertaining to timber management and the type of restrictions found suggested that timber growing was not the primary use of the properties on which the conservation easements were granted.

For development, the most common restriction was one prohibiting all agricultural, industrial, commercial, and residential activities. However, landowners often reserve rights for their own use or the use of their heirs. Typically, these development rights allow construction of a residence and associated structures. As with timber, the only affirmative right associated with development was the right to make compliance inspections on protected properties.

Forest land has many potential amenity uses compatible with the protection of open space. The most common amenity restrictions were related to recreational use, such as prohibitions against motorized vehicles and hunting and fishing. Grantors commonly reserved a broad right for low-impact recreational uses, which also often included hunting and fishing. New amenity uses arose from affirmative rights granted to the land trust; these rights were often extended to the public, such as recreational corridors providing access via hiking trails and waterways.

Discussion and Conclusions

Conservation easements have been publicized as a means of keeping land in its current use. Restrictions on development can preserve the current use feature, but new uses of open space can result. Also, a scattered or checkerboard pattern of protection may be a concern from a land use control perspective. To be most effective in protecting open space and avoiding fragmentation, conservation easements must be used in conjunction with other mechanisms that identify broader areas for protection.

Allowing public access for amenity uses of private forest land is an example of new land uses created by conservation easements. This change in the amenity potential of forest land can alter its utility for current owners and its value and appeal for future buyers. Private amenity enjoyment of the property is limited to activities reserved by the original grantor, with many potential uses compatible with open space foregone. The perpetual nature of most conservation easements dictates the need for careful design to achieve acceptable agreements.

In easements on forest land being managed for timber values, landowners must be careful to reserve rights essential to timber management. In addition to the right to harvest forest products, some provisions that may be necessary for southern forest land are rights to build temporary or permanent logging roads and trails, reforest with trees (including the use of improved genetic growing stock), restrict public access (if any) during harvesting periods and immediately after reforestation, and use appropriate silvicultural techniques such as prescribed fire, herbicides, and fertilization. Landowners making an informed decision to ban timber management activities should reserve the right to cut and remove timber damaged by natural disasters.

Needs for Additional Research

The use of conservation easements on productive forest land appears to be growing rapidly. Currently, there are more than 1,200 private land trusts in the United States that accept conservation easements as donations on land; a smaller number purchase conservation easements. In addition, many public agencies are seeking conservation easements as a means of affecting land use. A more comprehensive survey of all entities seeking conservation easements on forest land is needed to determine the acreage, location, and possible effects on timber supplies and other forest values.

Relatively little research has been done on the content of forest land easements, particularly those covering productive forest land. More analysis of the provisions of conservation easement deeds is needed, as are assessments of how well conservation easements are meeting the goals and objectives of the parties involved and the principles of sustainable forest management.

Acknowledgments

Data for table 8.5 were compiled and provided by Steven Bick, Principal Consultant, Northeast Forests, LLC, Thendara, NY.

Protective Regulatory Policies

Introduction

This section of the Assessment focuses on the protective regulatory (PR) policies that affect forestry in the South. Particular emphasis is placed on PR laws and policies protecting and enhancing water quality.

PR policies and laws safeguard society by limiting or mandating certain actions by the public and private sectors. They frequently rely on the "stick" of penalties rather than the "carrot" of subsidies or other incentives to accomplish their objectives. Only in a few instances and in limited jurisdictions do PR policies and laws specifically regulate forest management, but all forest land in the South is affected by PR policy. The effects depend on: (1) executive or jurisdictional level of the policy

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(Federal, State, or local); (2) forest land ownership category (Federal, State, industrial private, or NIPF); (3) owners' management objectives (multiple use, timber/fiber production, or habitat conservation); and (4) location with respect to urban centers, water bodies, wetlands, and designated critical habitats for endangered species.

Federal PR statutes affecting forest management in the South include:

- The National Environmental Policy Act of 1969;
- The Endangered Species Act of 1973;
- The Federal Water Pollution Control Act of 1972 and subsequent amendments (Clean Water Act);
- The Coastal Zone Act Reauthorization Amendments (1990);
- The Clean Air Act (1955) and subsequent amendments;
- The Federal Insecticide, Fungicide, and Rodenticide Act (1947) and subsequent amendments;
- The Organic Statutes of the USDA Forest Service, and the U.S. Department of the Interior (USDI) Fish and Wildlife Service and National Park Service;
- The Multiple-Use Sustained-Yield Act of 1960 and the National Forest Management Act of 1976;
- The Federal Land Policy and Management Act of 1976;
- The National Wildlife Refuge System Administration Act of 1966;
- The Wilderness Act (1964);
- The National Historic Preservation Act (1966); and
- The Administrative Procedure Act (1943) and subsequent amendments.

State PR laws and policies affecting forestry in the South include:

- Statutes governing the administration of State land;
- State water-quality statutes;
- State endangered species provisions;
- State pesticide use and application guidelines;
- State regulations for land disturbance and erosion control;
- Burning statutes; and
- Seed tree, forest conservation, and BMPs for private forests.

Local PR ordinances (covered in greater detail elsewhere in this chapter) affecting forestry in the South fall primarily in two main categories:

- Roads (access by logging equipment and weight limits), and
- Tree protection (primarily in urban and urbanizing areas).

Methods and Data Sources

When lawyers say that they are searching for the law on a particular subject, they typically mean that they are searching for enforceable provisions within the law. They are looking for those aspects of the law that allow some private or public legal action, a means of imposing fines or penalties to discourage wrongdoing, or provide a remedy for wrong already done. Accordingly, the primary source materials consulted were the legal statutes that establish PR policy. Secondary materials included books and technical papers about forest policy. The most extensive original research for this section was performed by students at the Tulane University School of Law and by the director of the Tulane Institute for Environmental Law and Policy.

Results—Federal Land

Federal land in the South is owned and managed by a variety of agencies, including the USDA Forest Service, the USDI Fish and Wildlife Service, the USDI National Park Service, the Department of Defense (branches of the military and the Corps of Engineers), the Department of Energy, the Bureau of Indian Affairs, and the Tennessee Valley Authority. Despite the number of agencies involved, only 9 percent of the forest land in the South is in Federal ownership; nearly 6 percent of forest is managed by the USDA Forest Service and 3 percent by other Federal agencies (Powell and others 1994).

Of the Federal PR policies listed in the introduction to this section, the Administrative Procedure Act, the National Environmental Policy Act, The National Historic Preservation Act, and the Endangered Species Act affect each of the Federal agencies with land in the South. The Administrative Procedure Act governs agency conduct in the processes of rulemaking and enforcement. In short, an agency's actions cannot be substantively arbitrary, capricious, or procedurally incompatible with its organic and other management statutes. The National Environmental Policy Act charges Federal Government agencies to coordinate environmental protection plans and programs, to incorporate amenity values in economic analyses, to involve the public, and, most importantly, to assess the impact of Federal actions on the quality of the environment. The National Historic Preservation Act requires that Federal agencies take into account the effects a project will have on historic resources and allow the Advisory Council on Historic Preservation the opportunity to comment on the effects of the project. The Endangered Species Act requires Federal agencies to (1) manage their land to conserve endangered and threatened species and (2) consult with the Fish and Wildlife Service to ensure that any agency action ". . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species . . ." (16 U.S.C.S. § 1536).

In addition to the Administrative Procedure Act, the National Environmental Policy Act, the Endangered Species Act, and the National Historic Preservation Act, each agency has management regulations stipulated by the Federal Code. These statutes differ, of course, depending on agency objectives. Regulations also differ widely in the amount of public solicitation required before significant actions are taken. With the exception of the National Environmental Policy Act regulations of the Council on Environmental Quality (40 CFR § 1506.6), most Federal agencies in the South conduct their routine land management programs with little input from the public. The major exception, however, is the USDA Forest Service, which manages two-thirds of the Federal land in the South. A closer look at its organic and management statutes is, therefore, warranted.

The Organic Act established the national forests to ". . . improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States . . . " (16 U.S.C. § 475). Timber is allowed to be sold "For the purpose of preserving the living and growing timber and promoting the younger growth on national forests . . . ” (16 U.S.C.A. § 476).

The Multiple-Use Sustained-Yield Act codified management of national forests for a variety of attributes other than timber and water. It states that: “. . . the National Forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes . . .” (16 U.S.C. § 528). “‘Sustained yield of the several products and services’ means the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the national forests without impairment of the productivity of the land” (16 U.S.C. § 531).

The National Forest Management Act was enacted in response to challenges over timber harvesting on national forest land. It has four key provisions for public oversight and management planning: (1) public participation in the planning process, (2) rules governing the preparation and revision of forest management plans, (3) guidelines for clearcutting, and (4) economic analysis of management alternatives. A possible fifth provision is the formal appeals process allowing members of the public to challenge forest management actions. Shortly after the act was passed, a committee of scientists was convened to assist the agency with writing the planning rules. This process was revisited in 1999 and 2000 by a second committee of scientists. Subsequently the planning rules were revised to make ecological sustainability the overriding objective for the management of the national forests (36 CFR Parts 217 and 219). Regardless of the objectives of management decisions, all activities must adhere (when pertinent) to the Clean Water Act, the Clean Air Act, and the Federal Insecticide, Fungicide, and Rodenticide Act as well as meet the substantive and procedural requirements of the Administrative Procedure Act, the National Environmental Policy Act, the Endangered Species Act, the National Historic Preservation Act, the Organic Act, and the Multiple-Use Sustained-Yield Act.

The impact of Federal policies on Federal land has been the recovery of forests, wildlife, and water quality on the vast majority of Federal properties in the South. Recreation opportunities have increased. National forest and other Federal land has provided a supply of timber that, while increasing as a percentage of the overall amount allocated by the Federal Government nationwide, has declined in amount in the past decade. This recovery has not come without expense: meeting the substantive and procedural requirements of the Administrative Procedure Act, the National Environmental Policy Act, the National Forest Management Act, the Multiple-Use Sustained-Yield Act, the Endangered Species Act, and other PR statutes makes the Forest Service, as well as other Federal agencies, a high-cost producer of timber and recreation. A final and unintended consequence is conflict between forest management and environmental protection statutes due to the incremental passage of individual PR policies. These conflicts reduce efficiency and defer management action (Hill 1997).

Results—State and Local Government Land

Collectively, the 13 Southern States own approximately 2 percent of the South’s timberland. Florida owns the most acres, followed by Tennessee, Arkansas, Mississippi, and North Carolina. This land is in State forests, State parks, State wildlife lands, and other special sites (historic, cultural, etc.). Less than 1 percent of the South’s timberland is in local and municipal ownership (Powell and others 1994).

As with the Federal agencies, the various State agencies charged with managing the States’ forest lands have differing objectives expressed in their organic statutes. As a general rule, State forestry agencies place proportionately more emphasis on timber management activities than do agencies administering wildlife, parks, and other areas. The amount of public participation in agency activity varies widely, depending upon agency objectives as well as the characteristics of each State’s administrative procedure code. Local and municipal management varies widely as well.

In addition to meeting the substantive and procedural requirements of administrative and organic codes, State land management agencies and municipalities must meet the requirements of Federal and State water-quality laws, Federal and State endangered species laws, and Federal and State air quality laws, as well as the Federal Insecticide, Fungicide, and Rodenticide Act and any State equivalents, should management actions necessitate compliance. Unless the State or local action is carried out with Federal funding, assistance, or concurrence, the provisions of the National Environmental Policy Act and National Historic Preservation Act do not apply. As with Federal land, the overall impact of these protective regulatory policies has been the recovery of forest vegetation and many of the game and nongame animal species on State land. State parks are a very important source of outdoor recreation, and State wildlife land provides extensive areas for fishing and hunting. Local and municipal holdings offer important amenity uses (Cubbage and others 1993).

Results—Private Land

Approximately 90 percent of the South’s timberland is privately owned. Forest industry holds almost 20 percent of the total; NIPF owners control the remaining 70 percent (Powell and others 1994). All owners are affected to a greater or lesser extent by Federal, State, and local PR policies, depending upon the location and environmental characteristics of their property.

Federal Statutes

The substantive and procedural Federal statutes (the National Environmental Policy Act, Administrative Procedure Act, National Historic Preservation Act, Multiple-Use Sustained-Yield Act, National Forest Management Act, Wilderness Act, etc.) do not apply to private owners unless the private owner is receiving Federal grants, assistance, or permits. Environmental quality/public health laws (Clean Water Act; Clean Air Act; Federal Insecticide, Fungicide, and Rodenticide Act; and Coastal Zone Act Reauthorization Amendments) and the Endangered Species Act do apply. Other statutes such as Occupational Safety and Health Administration workplace regulations and the Superfund, while important, have a relatively minor impact on forest management activities and will not be discussed here. Also not described in detail is the River and

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Harbors Act of 1899, which has the potential to affect private forestry activities that need a barge terminal.

Clean Water Act and Coastal Zone Act Reauthorization Amendments—Two main types of water pollution sources are recognized in the Clean Water Act: point sources, which have an identifiable input site such as a drainpipe; and nonpoint sources, which do not. Examples of the latter include farms, forests, cities, and municipalities. Interpretation and enforcement of statutes pertaining to nonpoint-source pollution in the Clean Water Act and Coastal Zone Management Act have largely been delegated to the States under Sections 319 and 303(d) of the Clean Water Act and under Section 6217 of Coastal Zone Act Reauthorization Amendments. These State-administered sections will be addressed in State implementation of the Clean Water Act and the Coastal Zone Act Reauthorization Amendments section of this chapter.

The one facet of nonpoint-source water pollution not delegated to the States is Section 404 of the Clean Water Act, which has been interpreted as a mechanism to regulate activities in jurisdictional wetlands in the United States. The Corps of Engineers (COE) has primary responsibility for enforcement of Section 404; the EPA has veto authority. The COE is authorized to grant (or to deny) individual and general permits for activities that may result in the discharge of dredge or fill materials into the waters of the United States. Section 401 requires States to certify that these permits comply with State water law. If the State denies certification, the Federal permit may not be issued. Selected activities (normal farming, silviculture, and ranching) are exempted from this permitting process under Section 404(f)(1) provided that the activities are part of established, ongoing operations.

Normal silvicultural activities are defined as timber harvesting, minor plowing, seeding, draining, and cultivation for producing timber. Maintenance of structures and ditches, as well as road construction and road maintenance activities are also exempted from permitting. However, this permit exemption is conditional upon the implementation of 15 Federal BMPs for maintaining and constructing roads. Additionally, mechanical site preparation activities require a permit in nine types of wetlands as defined in a 1995 COE memorandum (Burns 1996). Operators are exempted from the permit in other wetland types provided they utilize, as a minimum, the six BMPs for mechanical site preparation practices established in the memorandum.

Under 40 CFR 232.3(c)(1)(ii)(B), the scope of the forestry exemption is limited and "[a]ctivities which bring an area into farming, silviculture, or ranching use are not part of an established operation." In addition, "[a]n operation ceases to be established when the area in which it was conducted has been converted to another use or has lain idle so long that modifications to the hydrological regime are necessary to resume operations." The recapture provision of Section 404(f)(2) further limits the exemption by requiring a permit for otherwise exempted activities that convert a wetland into a new use, where the flow and circulation of waters are impaired or the reach of waters reduced. "A conversion of section 404 wetland to a non-wetland is a change in use of an area of waters of the United States" [40 CFR 232.3(b)]. Accordingly, Section 404 has the potential to affect both industrial and NIPF owners of forested wetlands depending upon the scope of operation proposed for their property as well as the intensity needed to accomplish management objectives.

Clean Air Act—The primary objective of the Clean Air Act is the protection of human health by limiting release of airborne fine particulate matter and gases such as ozone and sulfur oxides. Some forestry activities, primarily burning and soil disturbance in close proximity to urban centers, can be affected by the human health provisions of the Clean Air Act. However, the act's visibility standards are more often pertinent to forestry operations. While primarily utilized to protect vistas near class I wilderness areas, these standards are most frequently applied in the South to prevent accidents by minimizing smoke drift from prescribed burnings over highways. Landowners are liable for smoke-related accidents, but a State may share the legal burden of an operation that meets the conditions of a State-issued burning permit. As with the Clean Water Act and the Coastal Zone Act Reauthorization Amendments, the implementation, monitoring, and enforcement responsibilities are delegated to the States.

Federal Insecticide, Fungicide, and Rodenticide Act—Regulations about uses of herbicides, pesticides, and fertilizers influence some forestry operations. The Federal Insecticide, Fungicide, and Rodenticide Act requires that statutory restrictions, use precautions, and instructions for proper application and disposal specific to each chemical be included on labels of containers. The label also must indicate if application of the particular chemical is limited to trained and certified applicators. The EPA has regulatory and enforcement authority, although States, counties, municipalities, and other local jurisdictions may enact more stringent and preemptive supplemental use provisions that persons in those jurisdictions must abide by in addition to the Federal Insecticide, Fungicide, and Rodenticide Act.

Endangered Species Act—The Endangered Species Act was passed in 1973 to prevent the extinction of wildlife. Federal agencies must consult with the USDI Fish and Wildlife Service on the potential impacts to listed plants and animals and can "take" them only incidentally and with a permit. Private owners are prohibited from taking a threatened or endangered species of wildlife (vertebrates and invertebrates) but not plants. Taking is defined to include physical harm and harassment to the species as well as "significant habitat modification or degradation where it actually kills or injures wildlife" (16 U.S.C.S §1531). As some forest management activities have the potential to significantly modify or degrade habitat, this provision has affected both industrial and NIPF owners.

The 1982 amendments to the act have increased the number of management options for landowners whose properties harbor endangered species. These amendments establish provisions and special circumstances under Section 10 of the act that permit a taking (16 U.S.C.S. § 1539). Owners must first develop a detailed Habitat Conservation Plan. If the Fish and Wildlife Service determines that takings which might result from executing the plan (1) are not the purpose of the management activity, (2) are incidental to the management activity, and (3) will not "appreciably reduce the likelihood of the survival and recovery of the species in the wild," they may issue an Incidental Take permit (16 U.S.C.S. § 1539). Further refinements to this approach include Safe Harbor (50 CFR Part 13) and No Surprises (50 CFR Part 17) initiatives that can further limit liability for participating landowners if additional endangered species are found on their property.

State implementation of the Clean Water Act and the Coastal Zone Act Reauthorization Amendments— The Clean Water Act has two sections pertinent to silviculture: Section 319 and Section 303(d). Section 319 requires State Governors to submit a report to the EPA that:

- "identifies those navigable waters within the State which, without additional action to control nonpoint sources of pollution, cannot reasonably be expected to attain or maintain applicable water quality standards,"
- "identifies those categories and subcategories of nonpoint sources . . . which add significant pollution" to those subpar waters,
- "describes the process . . . for identifying best management practices" to control those problematic sources, and
- "identifies and describes State and local programs for controlling" nonpoint pollution sources [33 U.S.C.A. § 1329(a)(1)].

States are also required, "to the maximum extent practicable, [to] develop and implement a management program . . . on a watershed-by-watershed basis" [33 U.S.C.A. § 1329(a)(1)]. The act also provides that if a State fails to submit the report, the EPA is to prepare the report and submit it to Congress. Beyond that, there are no real sanctions. The principal motivation for States to comply with these requirements is a program of grant funds for the implementation of management programs.

States typically implement a significant part of their nonpoint-source pollution programs with those grant funds from the Federal Government under Section 319. Much of the activity in those programs concerns the encouragement of BMPs through educational activities, technical assistance, financial assistance, training, and demonstration projects. Some funds are used for BMP compliance monitoring. For example, South Carolina uses some of its 319 funds for a unique aerial surveillance program that examines the State's major streams on a monthly basis.

The second section of the Clean Water Act with implications for silviculture is the "total maximum daily load" program of Section 303(d) of the act. Somewhat dormant until a round of litigation beginning in the early 1990s, Section 303(d) requires that States:

- identify State waters from which point source effluent limitations are not sufficient to achieve water-quality standards,
- determine the total maximum daily loads that would be necessary to bring those waters up to water-quality minimums, and
- allocate those loads among sources in discharge permits and State water-quality plans [33 U.S.C.A. § 1313(d)].

Little of that had happened prior to the litigation of the past decade. The outcome of that litigation has been a series of agreements and court orders that have imposed schedules for the identification of the listing process and for the process of actually allocating loads among the various dischargers. Under those agreements and orders, States have as long as 12 years to complete the process (Houck 1999). Clearly, these total maximum daily load provisions hold the potential for significant impact on agriculture generally, and silviculture specifically, but the details are still very much in development. EPA guidance has argued that voluntary measures will be the "primary implementation mechanism" (Houck 1999). Southwide, silviculture appears to be a minor contributor to the problems of the waters that have been listed to date.

The Coastal Zone Act Reauthorization Amendments is another interface between Federal and State law with potential impacts on silviculture. In passing the act to amend the Coastal Zone Management Act in 1990, Congress added Section 6217 (16 U.S.C. §1455b), which requires States with Federally approved coastal zone management programs to:

- prepare a coastal nonpoint pollution control program that includes management measures to restore and protect coastal waters from the adverse impacts of polluted runoff;
- coordinate and integrate the State coastal zone management program with existing State and local water-quality plans and programs, particularly the State nonpoint-source management plan; and
- implement polluted runoff management measures that are consistent with the EPA's "Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters."

State plans under §6217 are voluminous. To date, their impacts on silviculture do not appear to be great, though the programs are still new.

State Statutes

The South is unique among regions of the United States in that none of its States has a comprehensive forest management act. Florida and Virginia achieve similar results with aggregated individual statutes, however. Florida's approach includes zoning and harvest notification at the county level and BMPs for wildlife, water, and aesthetics at the water management district level. Virginia utilizes a seed tree law in conjunction with voluntary BMPs and regulation of loggers. Kentucky's Forest Conservation Act currently stops short of comprehensive status. It does, however, establish guidelines for loggers and mandates BMPs. With those exceptions, few of the State-level PR policies directly address forestry and forest management. States do, however, have regulations to protect water quality, air quality, and endangered species, and to control pesticide use. These vary in complexity and rigor. For example, not all States have a list of threatened and endangered species, and those that do list species regulate forest management activities that may impact listed species only on State-owned lands. State air quality guidelines most often impact silviculture by limiting prescribed burning operations.

Water-quality laws affecting silviculture also vary among the States. Typically, a State's water law will prohibit pollution (variously defined) of a State's waters, except as it is allowed under the control of a State-issued permit. Silviculture is usually subject to the general prohibition, but it is often specifically exempted from the permitting requirement. Further, many States' laws only make the prohibition against pollution enforceable against silviculture operations if the conduct causing the pollution rises to a certain level of culpability, at least negligence. But the implementation of BMPs by a silviculture operator typically serves as proof that the operator has exercised due diligence or, at least, the standard of care of an ordinary person, thus defeating any legal finding of negligence. Generally, however, the implementation of BMPs will not protect against private lawsuits brought by neighbors or downstream persons who can demonstrate that they have been harmed and quantify that harm in monetary terms.

In the South, forestry BMPs are most often voluntary, but they are mandatory in a few States and in some special circumstances, such as for previous violators or around waters of special concern. In some States, counties have made BMPs mandatory. Typically, there are no preharvest notification requirements, and government agencies are only able to enforce BMP or water-quality requirements by searching out active harvesting operations. If violations are found, there is often a two-or-more-step process of trying to remedy the problem with education or technical assistance before sanctions are imposed.

Variations on the typical pattern include:

- A noticed general permit system in Florida, handled by five strong regional water management districts, with some prenotification requirements;
- Kentucky's Forest Conservation Act, which requires a master logger on site and mandates BMPs;
- Mandatory BMPs in some sensitive areas (and some counties) in Georgia;
- "Courtesy BMP exams" in South Carolina (exams typically result from aerial surveillance, and can affect an operator's market by publishing information that the operator has "failed an exam");
- Virginia's system that authorizes the State Forester to issue stop-work orders to prevent water pollution;
- Tennessee's program that (1) makes BMPs mandatory for operators who have previously been found responsible for water pollution and (2) requires preharvest notification for 2 years after an operator has been found guilty of a violation.

Impacts of PR Policies on Private Owners

While meeting environmental and human health goals, PR policies reduce the working area of industrial forests, alter management strategies, and increase costs. For example, demarcating streamside management zones and isolating endangered species habitat limits the amount of wood available for utilization. In certain instances, management plans are designed to prevent areas from becoming suitable endangered species habitat. Owners wishing to participate in the Safe Harbor and No Surprises Programs under the Endangered Species Act must develop their own Habitat Conservation Plans, which can be prohibitively expensive. Finally, PR policies motivate industry to initiate voluntary self-regulation programs in an effort to stave off the implementation of additional PR statutes that might be less palatable.

PR policies also have the potential to reduce working area and raise costs for NIPF owners. Some owners are impacted considerably more than others depending on the size, location, and environmental attributes of their property as well as their management objectives. Obviously, people who hold property mainly for its amenity values are affected less than those seeking to maximize the amount of income they can receive through the sale of wood.

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Local Forest-Related Ordinances

Introduction

In recent years, society's environmental sensitivity has increased, urbanites unfamiliar with the role of natural resources in the rural economy have migrated into rural areas, and growing cities have endeavored to maintain green space (Egan and Luloff 2000, Johnson and others 1997, Martus and others 1995). These trends have prompted local governments to adopt ordinances intended to protect the environment, aesthetics, open space, and public safety. These regulations influence how forest managers can operate on private land.

The effects of local ordinances on forest management are of concern to forestry professionals and forest owners. In addition to increasing forest owners' operating costs, regulation can create a patchwork of confusing, sometimes conflicting, requirements between different units of government (Martus 1992, Martus and others 1995, Provencher and Lassoie 1982, Shaffer 1991). Analysis of the impacts of local ordinances requires a firm understanding of their characteristics.

A study undertaken a decade ago identified units of local government that had enacted ordinances (Greene and Haines 1994, Martus 1992). The study also determined the provisions of each ordinance and categorized them by type. The current study was designed to update the earlier effort.

Methods

No centralized reporting system for county and municipal ordinances exists, so local forest-related ordinances were compiled from a variety of sources. The units of local government identified by Martus (1992) were contacted to find out whether they had enacted new ordinances. At the same time, the responding officials were asked for information on other counties or municipalities they were aware of that had enacted forest-related ordinances. Authors of articles on local regulation, representatives of the forestry agencies and forestry associations in each Southern State, extension foresters, university faculty members, consulting foresters, and other members of the forestry community also were contacted and asked for information on ordinances they were aware of. This process was continued until all leads were exhausted. Once identified, the units of government were contacted to obtain a copy of each ordinance.

Data Sources

Data for the study consisted of any law, ordinance, zoning provision, or other enactment that had been or could reasonably be used to restrict logging or silvicultural activities. Each enactment was examined to determine its date of adoption, regulatory objective, and provisions.

Table 8.6—Number of forest-related local ordinances in the South, by State, 1992 and 2000

State	Year 1992	Year 2000
	- - - - Number - - -	
Alabama	0	6
Arkansas	3	6
Florida	26	46
Georgia	41	116
Kentucky	0	0
Louisiana	25	52
Mississippi	1	7
North Carolina	1	16
Oklahoma	0	0
South Carolina	0	9
Tennessee	0	0
Texas	0	11
Virginia	44	77
Total	141	346

Results—Number of Ordinances

The Martus (1992) study identified 141 local ordinances in 7 of the 13 Southern States (table 8.6). Of the 135 units of local government that had enacted ordinances, 87 percent were counties or parishes. Four States—Virginia, Georgia, Florida, and Louisiana—accounted for 96 percent of the ordinances.

The current study found that the number of local ordinances in Southern States more than doubled between 1992 and 2000. The study identified 346 forest-related ordinances distributed among 264 units of local government in 10 Southern States (table 8.6). Of the enacting governments, 83 percent were counties or parishes. The proportion of ordinances passed by city governments increased from 8 percent of the total in 1992 to 13 percent in 2000. Neither study identified any local forest-related ordinances in Kentucky, Tennessee, or Oklahoma.

Of the 346 provisions, 341 had identifiable dates of enactment. Of these, 80 percent had been enacted in the last 10 years and 44 percent within the last 5 years (table 8.7). Thus, the number of local forest-related ordinances has essentially doubled every 5 years since 1970.

There are several reasons for the proliferation of local ordinances, including urban sprawl, exurbanization, social conflict, community mobilization, and protection of public investments. In addition, 18 percent of the ordinances resulted from State mandates. Virginia required local governments to enact watershed preservation ordinances pursuant to the Chesapeake Bay Preservation Act. Similarly, Florida mandated that county governments implement land development codes, some of which have silvicultural implications.

The “National Resources Inventory,” published in December 1999 by the USDA Natural Resources Conservation Service, reports that, on a national scale, forest acreage is declining at a rate of over 3 million acres per year due to urban sprawl. Urbanization is a major contributor to the proliferation of local ordinances in the form of tree protection and timber harvesting statutes.

Not only are cities expanding, but urban residents are migrating to rural areas seeking an improved lifestyle. This exurbanization introduces both social conflict and community mobilization as former city dwellers, unfamiliar with the role of natural resources in the rural economy, react strongly to the unpleasant appearance of harvested areas (Glickman 1999, Provencher and Lassoie 1982). Applying community organization and lobbying practices they are familiar with, the new residents press for ordinances to protect the sylvan setting they sought in moving from the city, with little regard for the effectiveness or impact of the ordinance on the traditional rural economy.

Many States in the South have a decades-old tradition of ordinances to protect public investments in roadways. The earliest identified ordinance was enacted in 1934 to protect parish rights-of-way and ditches from logging debris in Louisiana. Public protection ordinances remain the focus of local regulation in much of the South.

Regulatory objectives—The stated objectives of local ordinances provide insight into the attitudes of the adopting government and its constituents. Each ordinance identified in the study was placed into one of five categories:

1. Timber harvesting—Timber harvesting ordinances are adopted specifically to restrict forestry and silvicultural operations. All ordinances that referred to regulation of timber

Table 8.7—Number of forest-related ordinances enacted in the South, by type, 1992 and 2000

Type of ordinance	1992 No.	1992 %	2000 No.	2000 %
Timber harvesting	8	6	35	10
Public property protection	59	42	158	46
Tree protection	11	8	48	14
Environmental protection	19	13	26	8
Special feature protection	44	31	79	22

harvesting, skid trail and haul road construction, harvest methods, equipment, or any other silvicultural activity on private property were placed in this category. Common provisions include requiring management plans, harvest permits, adherence to State BMPs, and streamside management zones (SMZs). Of the ordinances identified in the study, 10 percent were in this category in 2000 (table 8.7).

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2. Public property protection—Ordinances in this category are enacted to protect public investments in roadways and bridges and to protect the safety of the traveling public. They place operating limits on heavy vehicles, including log trucks; prohibit accumulation of mud and debris on roadways; restrict interference with traffic flows; and protect against damage to roads, bridges, and culverts. Typical requirements include the posting of surety or cash bonds, hauling permits, placement of culverts in county ditches, and posting of warning signs at points of egress. Local ordinances in many areas of the South emphasize protection of public property and safety. Of the 346 ordinances identified, 46 percent were in this category (table 8.7).

3. Tree protection—Tree protection ordinances are associated with preservation of trees in areas that are being cleared for development. Common provisions include requiring tree-cutting permits, management or erosion-control plans, basal-area retention thresholds, replanting, and use of buffer strips. Landscaping laws were beyond the scope of the study. Of the ordinances identified, 14 percent were in this category (table 8.7).

4. Environmental protection—The purpose of ordinances in this category is to protect the general environment from land disturbing activities. Common provisions include requiring harvesting permits, soil erosion plans, use of SMZs, and buffer strips. Less than 10 percent of the ordinances identified were in this category (table 8.7).

5. Special feature protection—Special feature protection ordinances are adopted to protect specific areas that have scenic or environmental values. Examples are scenic river corridors, highway overlay districts, wetlands, view sheds, and special habitats. Common provisions include prohibiting tree cutting or requiring tree-cutting permits, requiring use of buffers, and notification of the local government. Over 20 percent of the ordinances identified in the study were in this category. Most were passed in Virginia, as mandated by the Chesapeake Bay Protection Act (table 8.7).

The focus of local regulation varied by State. Public property protection ordinances made up the majority of local regulations in Texas (55 percent), Alabama (67 percent), Georgia (72 percent), Arkansas (83 percent), Louisiana (86 percent), and Mississippi (100 percent). Tree protection laws dominated in North Carolina (40 percent), Florida (41 percent), and South Carolina (56 percent). Special feature protection ordinances mandated by the Chesapeake Bay Protection Act accounted for 78 percent of local forest-related ordinances in Virginia.

Preemptive/Preventive measures— Local ordinances affect the management alternatives available for private forests. By and large, the forestry community has responded by emphasizing ethical and stewardship-based forest management and by meeting with interested members of conservation groups, community organizations, and elected officials to show them what this approach to management looks like on the ground. By these activities, members of the forestry community seek to encourage the perception that further regulation is unwarranted. The study's data collection process, however, revealed that a variety of other, more proactive approaches have been used to prevent or preempt local regulation.

- State right-to-practice-forestry laws—State right-to-practice laws attempt to ensure that forest owners can continue to grow and harvest timber by limiting the ability of local units of government to restrict forestry practices. Kentucky, Louisiana, North Carolina, and Virginia have passed right-to-practice legislation. Kentucky's law appears to be the most successful in preempting local forest-related ordinances, since the study identified no such ordinances in that State. In contrast, the North Carolina law simply protects forestry from being classed as a "nuisance" activity in local ordinances. The Virginia law was effectively nullified by a recent State Supreme Court case (Ann F. Dail et al. v. Record No. 991591, April 2000). Local governments in that State now have court-issued authority to enact forest-related ordinances they deem justifiable.
- State forestry associations—In some instances, State forestry associations have succeeded in preventing adoption of local ordinances. For example, the Mississippi Forestry Association has organized county forestry associations that keep members aware of local problems and mobilize them to act promptly. The success of this approach is reflected in the relatively low number of local ordinances in Mississippi. In other instances, State associations have promoted an outcome-based approach to regulation as more effective and less costly than a process-based approach. Once ordinances are passed, State associations work through their legislative committees to ensure they are implemented fairly and efficiently.
- County road commissions—A little-used but effective strategy for preempting enactment of public property protection ordinances is the use of a county road commission composed of road superintendents, loggers, and foresters. Macon County, AL, for example, uses such a system to prevent roadway damage by having the forest industry supervise itself. If a problem arises, the commission works to correct it in a timely manner in order to avoid county intervention and the possibility of regulation.
- Private forestry interests—Forest products companies as well as NIPF owners are affected by local ordinances. Many firms utilize their foresters to keep track of local governments that show interest in developing ordinances. Action can then be taken to voluntarily correct problems before they lead to regulation.

In a few highly publicized cases, industry firms have sold large tracts of forest land to environmental organizations, land trusts, or government agencies. Examples include:

- The 1999 sale of 300,000 acres of Champion International land in three Northeast States to a coalition of organizations led by The Conservation Fund of Arlington, VA (The Conservation Fund 1999);

- The 2001 sale of 57,000 acres of Rayonier land in northeast Florida to State agencies in a deal brokered by The Nature Conservancy, to create a wildlife corridor between the Osceola National Forest and the Okefenokee National Wildlife Refuge (Rayonier 2001); and
- The recently announced sale of 100,000 acres of Weyerhaeuser land in Washington to Evergreen Forest Trust, to protect forest land near Seattle from development pressure (Society of American Foresters 2002).

Such sales protect the rural character of the forest land involved, slow the inception of regulation associated with urban expansion, and enhance public perception of the firms as good environmental citizens.

Discussion and Conclusions

Local regulation of forest activities has increased dramatically in recent years. The overall number of forest-related ordinances passed by local governments in the South increased from 141 in 1992 to 346 in 2000. Local ordinances occur in every Southern State except Kentucky, Oklahoma, and Tennessee, but they are especially prevalent in Georgia, Virginia, Louisiana, and Florida.

The mix of ordinances varies by State, but regionwide, public property protection ordinances are the most common, accounting for nearly half of all ordinances. Special feature protection ordinances are the next most common, followed by tree protection ordinances, timber harvesting ordinances, and general environmental protection ordinances. All types of ordinances increased in number between 1992 and 2000, but the relative proportion of public property protection, tree protection, and timber harvesting ordinances increased somewhat, while the relative proportion of special feature and environmental protection ordinances decreased. The proportion of forest-related ordinances passed by city governments also increased over the period.

Ordinances impact how forest managers can operate on private property. Ordinances do more than restrict forest management practices; they also increase operating expenses, reduce timber stumpage values, and create a patchwork of conflicting requirements across the landscape. These effects may be magnified in the South due to (1) the simultaneous trends of population growth and the shift of timber demand to the region, and (2) the importance of forest industry to Southern States and local economies (Cubbage 1991).

It seems likely that the number of public property protection ordinances will level off in the future. The number of special feature protection ordinances—mandated by State law to protect specific scenic or environmental features—may also remain relatively constant. Given the rapid rate of urban expansion, however, there is little reason to believe that proliferation of the other types of local ordinances will slow.

Approaches that have been used to avert enactment of new forest-related regulations in local areas include emphasizing ethical, stewardship-based forest management; education and mobilization of private forest owners by State forestry associations; cooperation among road officials, loggers, and foresters on county road commissions; and tracking and lobbying efforts by forest industry firms. Without successful amelioration measures, it will become impractical to practice forest management in increasingly large areas of the South. This condition may lead to additional large-scale sales of forest industry land to environmental organizations, land trusts, and government agencies or to State intervention in the form of right-to-practice-forestry laws or preemptive forest management acts.

Needs for Additional Research

The demographic and resource factors associated with localities experiencing rapid growth in forest-related ordinances need to be determined. The remaining objective of such a study should be to examine the correlation between such localities and measures of population—number, growth rate, education, income, and diversity, for example—and resource availability. Statistical analysis and a Geographic Information System will be used to seek insight into the factors associated with the proliferation of local regulation, both overall and by type of ordinance. The analysis should also indicate underlying rationales for the proliferation of local ordinances and provide a focus for future study.

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Private Property Rights and Right-to-Practice-Forestry Acts in the South

Introduction

Since the 1980s, local governments in the South have been enacting a growing number of ordinances that restrict forest practices. Historically, most local ordinances have been developed to protect the infrastructure, such as roads and bridges, but an increasing number are being directed at forest land management activities—timber harvesting practices, in particular. The previous section noted that there were 141 ordinances in the Southern States in 1992, 346 in 2000.

Local regulation, coupled with Federal and State laws and regulations enacted to control nonpoint-source water pollution or to protect wetlands, air quality, endangered species, and scenic waterways increasingly limit landowners' management options. The cumulative effect of this regulation is a complex environment in which to practice private forestry, and many southern landowners have reacted negatively.

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In addition to regulatory restrictions, forest land use has been increasingly subject to litigation claiming forestry activities constitute a nuisance, particularly in wildland-urban interfaces. Both regulation and nuisance claims are symptomatic of clashing urban and rural values in areas traditionally devoted to timber growing.

In response to increasing regulatory pressures and in concert with a growing national property rights movement, five Southern States have enacted property rights protection laws that: (1) require an evaluation by government agencies of proposed regulations for private property rights implications; and/or (2) provide a mechanism to compensate landowners for losses in property value. In addition, eight Southern States have enacted right-to-practice-forestry laws to protect landowners from nuisance actions for farm and forestry operations and to restrict the enactment of local ordinances restricting silvicultural practices. Legislation specific to the practice of prescribed burning has also been implemented in nine Southern States. These laws shield burners from nuisance suits and limit their liability for damages and injuries related to fire escapes and smoke intrusions.

Methods and Data Sources

This study is an update to research conducted by Haines (1995). Methods included standard legal research techniques. The primary source of information was the statutory code of each of the Southern States. In addition, forestry associations and forestry agencies in each State were contacted to obtain information about the current status of private property rights protection and right-to-practice-forestry laws enacted or proposed since 1995 when the Haines paper was published. The information provided included State statutes, supporting documents, position statements, and relevant published materials.

Results

In the South, four types of laws protect landowners' property values and promote the use of forest land for personal, societal, and ecological benefits. These include: (1) comprehensive property rights protection laws, (2) private property protection laws specific to agricultural and forest lands, (3) right-to-farm and right-to-practice-forestry acts, and (4) right-to-practice laws for specific forest activities, which so far have been limited to prescribed burning (table 8.8).

Comprehensive property rights protection laws—Comprehensive property rights protection laws make explicit the constitutional right to own and use property for a broad range of purposes; they create a legal remedy for landowners to recover losses in property value that result from government regulation. In addition, some of these acts require government entities to conduct an economic impact assessment of proposed laws or regulations that are likely to result in reductions of private property values. Most of the momentum to pass these laws occurred in the mid-1990s. Comprehensive private property rights protection laws were enacted in Florida, Texas, and Virginia in 1995. In the same year, bills were proposed but failed to pass in the legislatures of Alabama, Arkansas, North Carolina, and South Carolina. Legislation was again proposed in Alabama in 1997 and Arkansas in 1999, but failed again.

The enacted laws either provide for landowner compensation (Florida), analysis of economic impact (Virginia), or both (Texas). The Florida law does not provide a specific threshold for diminution (loss) of property value for landowner entitlement to compensation. Instead, subjective terminology is used as the measure

Table 8.8—Private property rights protection and right-to-practice forestry laws, dates of proposed and enacted legislation

	Types of laws			
State	Real property takings compensation/assessment	Farm and forest land compensation/assessment	Right to farm and practice forestry	Right to prescribe burn and limit liability
Alabama	Proposed 1995, 1997			Enacted 1995
Arkansas	Proposed 1995, 1999			
Florida	Enacted 1995		Enacted 1979	Enacted 1990
Georgia			Enacted 1995	Enacted 1992
Kentucky			Enacted 1996	
Louisiana		Enacted 1995		Enacted 1993
Mississippi		Enacted 1994	Enacted 1994	Enacted 1992
North Carolina	Proposed 1995		Enacted 1991	Enacted 1999
Oklahoma			Enacted 2000	
South Carolina	Proposed 1995		Enacted 2000	Enacted 1994
Tennessee			Enacted1982	
Texas	Enacted 1995			Enacted 1999
Virginia	Enacted 1995		Enacted 1994, 1997	Enacted 1997

of reduction in property value. Landowners must be “inordinately burdened” by government regulation. The Florida act also creates an optional mediation process that landowners may use to instigate a review of regulatory actions without filing a lawsuit.

The Texas law sets a threshold for compensation of property value loss at 25 percent. In addition, the Texas law requires government agencies to perform an impact assessment for any new laws, regulations, or ordinances that are likely to reach the 25 percent threshold to determine potential costs in landowner compensation, and to identify alternative solutions that would have less impact on private property rights.

The Virginia statute requires the State Department of Planning and Budget to conduct an economic impact analysis on the use and value of private property for proposed State legislation.

Laws to protect agricultural and forest land use—Laws to specifically protect agricultural and forest land use have been enacted in Mississippi (1994) and Louisiana (1995). The provisions of these acts are similar to the more comprehensive property rights protection laws. The takings threshold for diminution of agricultural or forest land value is 20 percent in Louisiana and 40 percent in Mississippi. The loss must be established for landowners to file claims for compensation. Louisiana’s law also requires an impact assessment for any proposed government regulations or local ordinances that may result in a diminution in the value of forest land.

Right-to-farm and right-to-practice-forestry laws—Laws that establish the right to farm and practice forestry by protecting landowners from nuisance suits were enacted between 1991 and 2000 in eight States: Florida, Georgia, Kentucky, Mississippi, North Carolina, Oklahoma, South Carolina, and Virginia. These acts recognize that agriculture and forestry are important to the economy and environment of the States, and that silvicultural practices may be discouraged by: (1) public and private nuisance actions, and (2) local ordinances and zoning regulations.

In general, these laws provide that agricultural and forestry activities that have been in existence for 1 year or more and are located in designated agricultural zones are protected from nuisance suits. An amendment to the Virginia law in 1997 expanded the protected area in that State beyond agricultural zones to include all areas legitimately used for forestry purposes.

Protection from these legal actions does not apply to operations conducted in a negligent or improper manner. In fact, the South Carolina, Florida, and Virginia acts specify that State BMPs must be implemented for landowners to be shielded from nuisance claims.

To varying extents, these acts also limit the power of local governments to adopt zoning regulations or ordinances that restrict or prohibit agricultural or forestry operations. Local restrictions that have prompted these provisions include: assessments of harvesting fees, requirements for public hearings and permits to harvest, outright prohibitions of harvesting, buffer and other requirements exceeding State BMPs, and prohibitions on prescribed burning.

A slightly different approach for legitimizing farm and forest practices was initiated in Georgia. Legislation was enacted there in 1995 to protect farm and forest practices through a deed notification requirement. Under this law, property owners must notify purchasers or lessees that the property they are acquiring lies within agricultural zones, that customary agricultural and forest uses of neighboring land may result in discomfort or inconvenience to them, and that these agricultural and forestry operations are permitted by law provided they conform with accepted standards and laws.

In 1994, in an opinion of the Tennessee State Attorney General, counties were determined to be prohibited from using zoning authority to regulate the clearcut method of harvest. The Attorney General based the opinion on the State’s Right to Practice Agriculture Law (1982), which defines the term “agriculture” to include forestry operations; the definition is the only reference to forestry in the law. Although an opinion is not binding, the findings of the Attorney General stymied the implementation of local ordinances in Tennessee.

Silvicultural operations may be similarly afforded protection from nuisance claims in other States’ right-to-farm acts as well. The interpretation of forestry operations as a component of agricultural activities or farming in these laws may provide additional protection of landowners’ rights to practice forestry.

However, in contrast to the Tennessee opinion, the Virginia Supreme Court issued a very narrow ruling regarding the State’s Right to Practice Forestry Law in April 2000 (Ann F. Dail, et al. v. York County et al. Record No. 991591). In this case, the landowner appealed local restrictions on clearcutting and buffer requirements in excess of State BMP standards and required approval of a forest management plan by York County. The Court ruled that: (1) approval of a management plan does not constitute a permit, which is prohibited by the State Right to Practice Forestry law; (2) State BMPs are voluntary and, therefore, counties could enact more stringent buffer requirements; and (3) local authorities could restrict the method of harvest, provided all harvesting was not precluded. The impact of this ruling in Virginia could be far reaching; some 48 local governments have ordinances, permit fees, or restrictive requirements for forestry. In addition, forest land in Virginia is being converted to other uses at a rate of about 50,000 acres per year (Forest Council of Virginia 1996).

Right-to-practice-prescribed-burning acts—In the past 10 years, nine Southern States have enacted legislation to authorize and promote the continued use of prescribed burning of forest land by limiting burners’ civil liability for damages or injuries resulting from fire or resultant smoke and providing protection from spurious nuisance suits. These laws define prescribed burning as a legal and socially beneficial activity that shall not be deemed a nuisance. These statutes were enacted in 1990 in Florida, in 1992 in Georgia and Mississippi, in 1993 in Louisiana, in 1994 in South Carolina, in 1995 in Alabama, in 1997 in Virginia, and in 1999 in North Carolina and Texas.

Three conditions must be met before burners can be afforded the liability protection established in these acts. The first condition is the presence of at least one certified burner at all times until the burn is completed. In Georgia, the burn manager does not have to be certified but must have burning experience. The second condition is the development of a written fire prescription or plan. The third is adherence to the rules and notification and permit procedures established under other laws.

In the past, burners have been shielded from liability under these laws, provided any damages or injuries were not a result of negligence. However, to further encourage burning in their States, the legislatures of Georgia and Florida have recently amended their laws to further shield burners from liability. Under these amendments, burners are liable only for damages or injuries resulting from gross negligence, a lesser degree of responsibility. In legal proceedings, the expanded protection could be crucial to burners. In Mississippi, an effort is underway to similarly broaden protection.

The Texas law is the only prescribed burning protection act that addresses insurance coverage for burners; only burners with $1 million of liability coverage are afforded protection.

Implications

Private property rights protection and right-to-farm and right-to-practice-forestry acts are an attempt to provide an equitable balance between the goals of society and the constitutional rights of private landowners to manage their land for personal benefit. These laws provide safeguards for protecting the public from practices conducted in a negligent manner while protecting landowners' property rights and encouraging sustainable forest management practices. Since most of this legislation has been passed in recent years, the impact on the operational environment for forestry is unclear.

As previously discussed, the findings of the Tennessee Attorney General in his opinion and the decision of the Supreme Court in Virginia regarding the power of local governments to regulate forest operations are in sharp contrast. Legal interpretations through the courts in each State will likely play a pivotal role in determining the impact of these laws.

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Literature Cited

Alig, R.J.; Dicks, M.R.; Moulton, R.J. 1998. Land use dynamics involving forestland: trends in the U.S. South. In: Kluender, R.A.; Smith, N.B.; Corrigan, M.M. Proceedings of the 1998 Southern Forest Economics Workers meeting. Monticello, AR: University of Arkansas: 9-23.

Amacher, G.S.; Aust, W.M.; Grebner, D. [and others]. 1997. Landowners' financial returns to reforestation of marginal farmlands in the Mississippi Alluvial Plain: estimates, interpretations, and policy implications. Monogr. 185. Blacksburg, VA: Virginia Water Resources Research Center. 85 p.

Anderson, J.E. 1993. Use-value property tax assessment. Land Economics. 69(3): 263-269.

Best, C.; Wayburn, L. 1996. Conservation easements: rewards for stewardship. In: Baughman, M.J.; Goodman, N., eds. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 118-124.

Bick, S.; Haney, H.L., Jr. 1999. Timber, development, and amenity values associated with conservation easements in the South. In: Abt, K.L.; Abt, R.C., eds. Proceedings of the 1998 southern forest economics workshop. Raleigh, NC: North Carolina State University, Department of Forestry: 208-211.

Bick, S.; Haney, H.L., Jr. 2001. The landowner's guide to conservation easements. Dubuque, IA: Kendall/Hunt Publishing Co. 179 p.

Bick, S.; Haney, H.L., Jr.; West, C.D. 1998. A national overview of conservation easements on forestland. In: Meeting in the middle: Proceedings of the Society of American Foresters 1997 national convention. SAF-98-02. Bethesda, MD: Society of American Foresters: 225-230.

Bick, S.; Haney, H.L., Jr.; West, C.D. 1999. How conservation easements address forest values. In: Great lakes, great forests: Proceedings of the Society of American Foresters 1998 national convention. SAF-99-01. Bethesda, MD: Society of American Foresters: 232-236.

Birch, T.W. 1996. Private forest-land owners in the United States, 1994. Resour. Bull. NE-194. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 183 p.

Boelhower, M.E.; Van Ryn, T. 1996. Conservation easements and forestry: building better partnerships. In: Baughman, M.J.; Boodman, N., eds. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 125-136.

Brockett, C.D.; Gottfried, R.; Evans, J.P. 1998. Economic incentives and institutional innovations to promote forest preservation on private lands: a case study from the Southern United States. Landscape Anal. Lab Res. Rep. 3. [A Report of the Research Group in Conservation Biology and Sustainable Development at the University of the South]. http://lal.sewanee.edu/reports.html [Date accessed: July 2, 2002].

Bullard, S.H.; Straka, T.J. 1988. Structure and funding of State-level forestry cost-share programs. Northern Journal of Applied Forestry. 5: 132-135.

Burns, D.R. 1996. Guidance on the application of best management practices to mechanical silvicultural site preparation activities for the establishment of pine plantations in the Southeast. Federal Register. 61(39): 7242-7245.

Busby, R.L.; Ward, K.B.; Baldwin, V.C., Jr. 1990. COMPUTE_MERCHLOB: a growth and yield prediction system with a merchandising optimizer for planted loblolly pine in the west gulf region. Res. Pap. SO-255. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 22 p.

Busby, Rodney; Haines, Terry. 1994. Chemical control and cost-share programs profitable for southern forestry investments. In: Proceedings, 47th annual meeting of the southern weed science society. Southern Weed Science Society: 127-131.

Carlen, S.A. 1978. Property tax assessment procedures on timberlands in the United States: 1966-1976. Blacksburg, VA: Virginia Polytechnic Institute and State University. 322 p. M.S. thesis.

Coughlin, R.E.; Berry, D.; Plaut, T. 1978. Differential assessment of real property as an incentive to open space preservation and farmland retention. National Timber Tax Journal. 31(2): 165-179.

Cubbage, F.W. 1991. Public regulation of private forestry: proactive policy responses. Journal of Forestry. 89(12): 31-35.

Cubbage, F.W.; O'Laughlin, J.; Bullock, C.S. 1993. Forest resource policy. New York: John Wiley. 562 p.

Department of Forestry and Natural Resources, Purdue University. National Timber Tax Website. 2001. [Web page]. http://www.timbertax.org. [Date accessed: January 10, 2001].

Dillman, D. 1978. Mail and telephone surveys: the total design method. New York: John Wiley. [Number of pages unknown].

Doherty, Brian A. 1993. State use-value statute summaries. Unpublished summaries of State use-value statute regulations and rules. On file with: Southern Research Station, Room T-10034, U.S. Postal Service Building, 701 Loyola Ave., New Orleans, LA 70113.

Dubois, M.R.; McNabb, K.; Straka, T.J.; Watson, W.F. 1995. Costs and cost trends for forestry practices in the South. 30th man. ed. Forest Farmer. 54(3): 10-17.

Egan, A.E.; Luloff, A.E. 2000. The exurbanization of America's forests: research in rural social science. Journal of Forestry. 98(3): 26-30.

Ferguson, J.T.; Spinelli, M.A. 1998. Measuring the effectiveness of use-value taxation. Assessment Journal. September/October: 56-62.

Flick, Warren A.; Horton, Donald A. 1981. Virginia's reforestation of timberlands program: an economic analysis of the first six years. Southern Journal of Applied Forestry. 5(4): 195-200.

Forest Council of Virginia, 1996. Senate Bill 592. Private forest land conservation; position statement. Richmond, VA: Forest Council of Virginia. 2 p.

Gardner, A.B.; Olson, S.C.; Haney, H.L., Jr.; Siegel, W.C. 1984. Election by forest estates of certain Federal estate tax provisions. Journal of Agricultural Taxation and Law. 6: 400-428.

Glickman, D. 1999. Remarks: national summit on private lands. Release 0479.99. Ames, IA: U.S. Department of Agriculture. 6 p.

Gloudemans, R.J. 1974. Use-value farmland assessments: theory, practice and impact. Chicago: International Association of Assessing Officers. 73 p.

Gottfried, R.; Haddican, M.; Presley, J. 1999. Does Tennessee's Greenbelt Program really maintain forest cover? [A Report of the Research Group in Conservation Biology and Sustainable Development at the University of the South]. [Number of pages unknown]. http://lal.sewanee.edu/reports.html [Date accessed: July 2, 2002].

Graetz, M.J. 1997. The decline (and fall?) of the income tax. New York: W.W. Norton and Company. 323 p.

Greene, J.L. 1995. State tax systems and their effects on nonindustrial private forest owners. In: Proceedings of the 1994 SAF national convention. Bethesda, MD: Society of American Foresters: 414-419.

Greene, J.L. 1998. The economic effect of Federal income tax incentives in southern timber types. In: Proceedings of the 1997 SAF national convention. Bethesda, MD: Society of American Foresters: 231-241.

Greene, J.L.; Beauvais, T. 2002. Estimating the cost of forest-based income tax incentives to promote clean water. In: Forest law and economics: Proceedings of the 2001 southern forest economics workshop. Auburn, AL: Auburn University, School of Forestry and Wildlife Sciences: 24-30.

Greene, J.L.; Haines, T.K. 1994. Estimating the effect of State and local regulation on private timber supply. In: Wear, D.N.; Talmon, J., comps. Proceedings of the southern forest economics workshop. Durham, NC: Duke University: 119-129.

Gulf South Research Institute. 1983. A review of use-value procedures in selected States. Baton Rouge, LA: Gulf South Research Institute; final report. [Number of pages unknown]. [Prepared for Louisiana Tax Commission].

Haines, T.K.; Cleaves, D.A. 1995. State governments move to protect forest landowners. Forest Farmer. 54(6): 9-11.

Haines, Terry. 1995. Federal and State forestry cost-share assistance programs-structure, accomplishments, and future outlook. Res. Pap. SO-295. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 44 p.

Haney, H.L., Jr.; Hoover, W.L.; Siegel, W.C.; Greene, J.L. 2001. Forest landowners' guide to the Federal income tax. Agric. Handb. 718. Washington, DC: U.S. Department of Agriculture, Forest Service. 157 p.

Haney, H.L., Jr.; Siegel, W.C. 1993. Estate planning for forest landowners: what will become of your timberland? Gen. Tech. Rep. SO-97. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 186 p.

Harrell, James B. 1989. Federal and State cost-share programs for forest farmers. Forest Farmer. Nov./Dec.: 20-27.

Harris, T.; DeForest, C. 1994. Policy implications of timberland loss, fragmentation, and urbanization in Georgia and the Southeast. In: Wear, D.N.; Talmon, J., comps. Proceedings of the southern forest economics workshop. Durham, NC: Duke University: 70-83.

Haynes, R.W., tech. coord. [In press]. An analysis of the timber situation in the United States: 1997-2050. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

SOCIAL

Herman, Tom. 2001. A change in death and taxes? Debating the options for an estate-tax overhaul. The Wall Street Journal. February 26: 13 (col 1).

Hickman, C.A. 1982. Use-value assessment of forest lands in the South. In: Granskog, James E.; Haney, Harry L. How to cope with hard times: Proceedings of the 1982 southern forest economics workshop. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 115-135.

Hickman, C.A. 1983. Use valuation of forest lands in the United States. International Real Estate Journal. 4(1): 62-70.

Hickman, C.A.; Gayer, P.D. 1983. Use valuation of Louisiana's rural lands: short-run fiscal impacts. Res. Pap. SO-197. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 42 p.

Hickman, C.A. 1989. Inconsistent forest property tax policies within selected Southern States. Res. Pap. SO-253. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 7 p.

Hill, B.T. 1997. Forest Service decision-making. Testimony of the United States General Accounting Office before the Subcommittee on Forests and Public Lands. GAO/T-RCED-97-81. Washington, DC: U.S. General Accounting Office. 145 p.

Hoover, William L.; Siegel, William C.; Myles, George A.; Haney, Harry L. 1989. Forest owner's guide to timber investments, the Federal income tax, and tax recordkeeping. Agric. Handb. 681. Washington, DC: U.S. Department of Agriculture. 104 p.

Houck, O.A. 1999. The clean water act TMDL program: law, policy, and implementation. Washington, DC: Environmental Law Institute. 388 p.

Howard, T.E. 1985. Estate planning for nonindustrial forest owners. Land Economics. 61(4): 363-371.

Izlar, Bob. 1983. South Carolina's forest renewal act. Tech. Rel. 83-R-26. Washington, DC: American Pulpwood Association. 2 p.

Johnson, R.L.; Alig, R.J.; Moore, E.; Moulton, R.J. 1997. NIPF landowners' view of regulation. Journal of Forestry. 95(1): 23-28.

Kotkin, J.; Siegel, F. 2000. Digital geography: the remaking of city and countryside in the new economy. Indianapolis, IN: Hudson Institute. [Number of pages unknown].

Krietemeyer, S.W.; Flick, W.A.; Hickman, C.A. 1987. The initial impact of current-use assessment in Alabama. Assessment Digest. 9(2): 18-24.

Land Trust Alliance. 2000. Land trusts in the United States, data from the 1998 National Land Trust Census. http://www.lta.org/censum.html. [Date accessed: October 6].

Lucas, G.K. 1963. Death taxes as related to the forest enterprise. Auburn, AL: Auburn University. [Number of pages unknown]. M.S. thesis.

Manning, Robert F.; Windish, David F. 2001. Tax analysts' guide to the Economic Growth and Tax Relief Reconciliation Act of 2001. Tax Notes. 91(12): 1777-1810.

Marcum, Gary F. 1993. Forest practices and water quality in Virginia. Tech. Rel. 93-P-11. Washington, DC: American Pulpwood Association. 9 p.

Martus, C.E. 1992. The distribution and objectives of local forestry-related ordinances in the United States. Blacksburg, VA: Virginia Polytechnic Institute and State College. 308 p. M.S. thesis.

Martus, C.E.; Haney, H.L., Jr.; Siegel, W.C. 1995. Local forest regulatory ordinances: trends in the Eastern United States. Journal of Forestry. 93(6): 27-31.

Morrow, R.; Fritschi, B. 1997. Banking on timber. Forest Landowner. 56(6): 25-28.

Nelson, A.Z. 1941. Status of official instructions for assessing forest land. Washington, DC: U.S. Department of Agriculture, Forest Service. 28 p.

Newman, D.H.; Brooks, T.A.; Dangerfield, C.W. 2000. Conservation use valuation and land protection in Georgia. Forest Policy and Economics. (3-4): 257-266. Vol. 1.

Norris, F.W. 1995. Timber mart-south: 1995 yearly summary. Highlands, NC: Timber Mart-South: 20(4): 1-4.

Northern Forest Lands Council, comp. 1994. Appendix E-subcommittee research findings: land conversion. Concord, NH: Northern Forest Lands Council. A-17 to A-22.

Peters, D.M.; Haney, H.L., Jr.; Greene, J.L. 1998. The effects of Federal and State death and gift taxes on nonindustrial private forest lands in the Midwestern States. Forest Products Journal. 48(9): 35-44.

Powell, Douglas S.; Faulkner, Joanne L.; Darr, David R. [and others]. 1993. Forest resources of the United States 1992. Gen. Tech. Rep. RM-234. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 132 p. + map.

Provencher, R.W.; Lassoie, J.P. 1982. Pros and cons of local logging ordinances. Conserv. Circ. Ithaca, NY: Cornell University, New York Extension Service. 9 p. Vol. 20 (3).

Rayonier. 2001. Rayonier sells 57,000 acres of timberland in Florida for $60 million. Rayonier news: press releases. http://www.rayonier.com/ir_main.asp?ParLvl=21&TOCLvl=2&Exp=False&SecID=22&UserClick=Y&con=ccbn&irurl=http://www.corporate-ir.net/ireyeir_site.zhtml?ticker=RYN~script=410~layout=6~item_id=166660 [Date accessed: July 2, 2002].

Sampson, R.N.; DeCoster, L.A. 1997. Federal programs for private forestry: a reader on programs and options. Washington, DC: Forest Policy Center, American Forests. 100 p.

Shaffer, R.M. 1991. Forestry by regulation: California style. Virginia Forests. 47(3): 15-18.

Siegel, W.C. 1978. Historical development of Federal income tax treatment of timber. In: Haney, H.L., Jr.; Gunter, J.E., comps. Proceedings of the forest taxation symposium. For. and Wildl. Ser. 2-78. Blacksburg, VA: Virginia Polytechnic Institute and State University, School of Forestry and Wildlife Resources: 17-25.

Society of American Foresters. 2002. Conservancy to buy Weyerhaeuser land: financing could be new model for forest conservation. The Forestry Source. 7(2 Feb): 5.

Sutherland, C.F., Jr. 1978. The importance of death taxes to forestry. In: Haney, H.L., Jr.; Gunter, J.E., comps. Proceedings of the forest taxation symposium. For. and Wildl. Ser. 2-78. Blacksburg, VA: Virginia Polytechnic Institute and State University, School of Forestry and Wildlife Resources: 81-91.

Sutherland, C.F., Jr.; Tedder, P.L. 1979. Impacts of Federal estate taxation on investments in forestry. Land Economics. 55(4): 510-520.

The Conservation Fund. 1999. Chesapeake, northern forest protected. Common Ground. 10(6 Sep/Oct): 1, 6.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1999. National resources inventory: summary report, December 1999. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. [Number of pages unknown].

U.S. Department of Agriculture, Natural Resources Conservation Service. 2000. Summary report: the national resources inventory, 1997 (Revised December 2000). http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/report.pdf. [Date accessed July 2, 2001].

U.S. Department of Commerce. 1992. Statistical abstract of the United States, 1994. Washington, DC: U.S. Government Printing Office. [Number of pages unknown].

Walden, J.B.; Haney, H.L., Jr.; Siegel, W.C. 1987. The impact of recent changes in State and Federal death tax laws on private nonindustrial forest estates in the South. Southern Journal of Applied Forestry. 11: 17-23.

Wall, B.R. 1981. Trends in commercial timberland area in the United States by State and ownership, 1952-77, with projections to 2030. Gen. Tech Rep. WO-31. Washington, DC: U.S. Department of Agriculture, Forest Service. 28 p.

Whitt, R. 1992. '90 timber tax cut goes awry. Atlanta Journal Constitution. December 27: A (col. 1).

Williams, E.T. 1956. State guides for assessing forest land and timber. Washington, DC: U.S. Department of Agriculture, Forest Service. 52 p.

Williams, E.T. 1967. State guides for assessing forest land and timber. 1966. Misc. Publ. 1061. Washington, DC: U.S. Department of Agriculture, Forest Service. 91 p.

Williams, E.T.; Canham, H.O. 1972. The productivity concept in forest taxation. Forest Science. 18(1): 3-20.

What motivates private forest landowners to manage their forest land, and how are their management objectives formed?

Chapter 9: Motivation for Private Forest Landowners

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Key Findings

- Private timberlands in the South are held in more than 4.9 million tracts. The number of private ownerships is increasing, and tract sizes are decreasing.
- In 1994, two-thirds of all private timberland tracts were <10 acres, but they accounted for only 4 percent of the total private timberland acreage. Tracts >500 acres represented nearly one-half the total private acreage.
- Southern nonindustrial private forest (NIPF) owners have widely diverse ownership use and management objectives, beliefs, values, and interests.
- Primary reasons for NIPF ownership in the South include rural area residence, land investment growth, farm or domestic use, enjoyment of natural resources, estate purposes, and outdoor recreation.
- Although representing a small percentage of all private timberland owners, owners interested primarily in timber production make management decisions for more than one-third of all private timberland.
- Available research information is insufficient to define an average private southern forest landowner.
- Factors that can influence the ways in which private owners manage their land include income, personal values, tract size, residence, long-term plans, knowledge of alternative management options and benefits, taxation policies, and government assistance programs.
- Research information about objectives or behaviors of subgroups of the general southern NIPF population is limited and inconclusive, except for those who have participated in government cost-share programs.
- Little research information is available about owner corporations, partnerships, clubs, and other entities, including timber investment and management organizations (TIMOs). Nonindustrial corporate owners control 11 percent of the South's total private timberland acreage. Forest industries control 21 percent of the total private acreage.
- In 1994, 1.4 million private owners had intentions to harvest timber on more than 112 million acres within the following decade. The <1 percent of owners holding tracts >500 acres controlled 65 percent of the timberland intended for harvest.
- In 1994, private owners who indicated they would never harvest timber from their land controlled only 12 percent of the total private timberland acreage.
- Government cost-share programs have assisted a small percentage of the total NIPF owner population. The programs seem to be most popular with owners interested in timber and wildlife production. Related motivational factors include management costs, available capital, taxes, and resource commodity values.
- Many southerners, including forest landowners, feel that private property rights are important but secondary to environmental protection needs.

Introduction

The South's 215 million acres of forest land are among the most productive in the Nation. About 201 million acres of this land are classed as timberland, capable of producing at least 20 cubic feet of industrial wood each year and not withdrawn from timber utilization. Private holdings account for about 89 percent of the total timberland acreage. The major private owner groups are NIPF owners and forest industry owners. NIPF owners alone control 79 percent of the total private timberland acreage. How the South's private forests are used and managed will have important impacts on future supplies of forest-resource-related goods, services, and benefits. Identifying and understanding the characteristics of private owners and the major factors that may influence land use and management will be important to the development of effective owner assistance programs, as well as for predicting future resource conditions.

Methods

Information presented here is based solely on a review of existing data, papers, and published literature.

Data Sources

A primary source of data is the nationwide Forest Inventory and Analysis (FIA) project of the USDA Forest Service, undertaken in cooperation with the National Association of State Foresters and the USDA Natural Resources

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Conservation Service. A description of inventory procedures used to collect survey data in the South is presented in chapter 16. Other sources of information reviewed for this chapter included papers and articles published primarily during the last 10 years that describe acreage, demographics, attitudes, and management behavior of private forest owners in various Southern States. Selected FIA data on regional timberland acreage, as well as selected State and Private Forestry Cooperative Program accomplishments data for Southern States, were obtained from unpublished USDA Forest Service sources. The term "forest land" as used in this chapter refers to tracts at least 1 acre, that are at least 10-percent stocked with trees of any size and are not currently developed for nonforest use.

Results

Ownership

The 13 Southern States contain an estimated 215 million acres of forest land. About 201 million acres are classified as timberland (chapter 16). In 1999, an estimated 179 million acres of the South's timberland (89 percent) were in private ownership (chapter 16). Birch (1996) found southern private timberlands to be in 4.9 million tracts owned or controlled by private individuals and legal entities, including corporations, clubs, trusts, partnerships, American Indian tribes, and Native American corporations. More than three-quarters of all private owners owned only one tract. More than two-thirds of these tracts were located <1 mile from owners' residences.

In 1999, about 21 percent (37 million acres) of the South's private timberlands were owned by forest industries (chapter 16). In 1994, forest industries represented <1 percent of all private ownership units (Birch 1996). Although forest industry timberland acreage slowly increased from 1953 until 1989, it declined by about 1 million acres (3 percent) between 1989 and 1999 (chapter 16).

In 1994, an estimated 4.7 million individual owners held the largest share of private southern timberland. Individual owners compose the core of the group commonly referred to as NIPF owners (Moulton and Birch 1995). Almost 95 percent of all private timberland owners in the South are in this group (Birch 1996). In 1999, they controlled 63 percent of the total private timberland acreage (chapter 16).

Since African-Americans constitute the largest group of minority rural landowners in the South, they are probably also the largest group of minority NIPF owners. No statistics are available, however, regarding overall minority ownership characteristics (Shelhas 2000). Gan and others (1999) have reported data about a limited number of minority NIPF owners in two southeastern Alabama counties. Selected owner information from this study is included in various sections of this chapter.

In 1994, nonindustrial corporations, partnerships, clubs, associations, and other entities held nearly 5 percent of the 4.9 million private timberland tracts in the South (Birch 1996). Acreage in nonindustrial corporate ownerships increased by about 25 percent from 1982 to 1999. By 1999, corporate owners accounted for 11 percent of private timberland acreage (chapter 16). Nonindustrial corporate owners include various timber and investment management organizations (TIMOs), such as banks, insurance companies, agribusiness, and investment and development firms (chapter 16). In 1999, TIMOs held about 4 million acres of timberland throughout the South (chapter 14).

Information about timberland ownership by ecological province is presented in chapter 16. As illustrated in figure 16.35 and table 16.32 of that chapter, private timberland is represented in all 11 provinces. Public, private corporate, and private forest industry ownerships are concentrated in the Outer Coast Mixed and Southeast Mixed Provinces (chapter 16).

Nearly 2 million new, predominately NIPF owners acquired their land sometime between 1980 and 1994. Of these new owners, more than one-fifth acquired land between 1990 and 1994 alone (Birch 1996). Many undoubtedly inherited land. Amacher and others (1998), for example, found that almost one-fourth of Virginia's NIPF owners had obtained their land through inheritance. Jacobson (1998) reported the same situation for three-tenths of Florida NIPF owners.

The acreage and number of all private timberland tracts in the South increased at a moderate rate between 1978 and 1994, while average tract size decreased. During that period, all private timberland ownerships increased by nearly one-third, or 1.1 million units. Acreage held in tracts of <10 acres increased by 51 percent. Other acreage changes included: 10- to 99-acre tracts (+25 percent); 100- to 499-acre tracts (-15 percent); 500- to 999-acre tracts (-9 percent); 1,000+-acre tracts (+9 percent) (Moulton and Birch 1995). For a comprehensive review of changes and trends in forest land and timberland over the past 50 years, see chapter 16.

By 1994, about two-thirds of all private timberland tracts were <10 acres. Together, however, these small tracts accounted for only 4 percent of the South's total private timberland acreage. The majority of all timberland (70 percent) was held in tracts of at least 100 acres, by <6 percent of all owners. Tracts >500 acres alone represented nearly one-half the total private timberland acreage (Birch 1996).

Private Owner Occupation, Income, and Education

Information about NIPF owner demographics in the South is sketchy. Kluender and Walkingstick (2000), for example, found that >40 percent of Arkansas NIPF owners were retirees. Birch (1996) reported that 29 percent of all southern private timberland owners were white-collar workers. Retirees and blue-collar workers were two other dominant classes. Together, these three classes accounted for 72 percent of all private owners. Retirees and white-collar workers each owned around 20 percent of all private timberlands.

Farmers accounted for only 6 percent of all southern owners and held only about 9 percent of all private timberland. As noted in chapter 16, farmer-owned timberland has been declining for many decades. Fifty years ago, farmers owned about two-thirds of the South's timberland (chapter 16).

Limited State-level research findings suggest that annual income and educational levels of NIPF owners probably vary considerably, just as they do for people in general. Amacher and others (1998) found that the average annual income of NIPF owners in rural southwestern Virginia was about $48,000. Landowners in the more urbanized, central Virginia region, however, had an average yearly income of >$91,000. The modal subjects of a Florida NIPF study had at least a bachelor's degree and a household income of >$50,000 annually. Kluender and Walkingstick (2000) found about 18 percent of NIPF owners in Arkansas had not graduated from high school, about 30 percent had graduated from high school, and the remainder either had some college education (25 percent) or were college graduates (26 percent). Almost half of these landowners reported household incomes of at least $35,000 per year, while 28 percent averaged <$20,000 annually (Kluender and Walkingstick 2000). The median annual household income of NIPF minority landowners in two Alabama counties was between $30,000 and $39,999, with two-fifths having incomes of at least $40,000. Four-fifths had at least a high school education (Gan and others 1999).

The large numbers of retiree NIPF owners in the South, as well as other research findings, suggest that many timberland owners are probably between 50 and 60 years old. Hodge (1996) reported that about 50 percent of Virginia NIPF owners were older than 60. Another third were 46 to 60 years old. Virginia landowners studied by Amacher and others (2000) had an average age of 60 years. About 60 percent of new NIPF forest owners in Georgia were older than 55 (Newman and others 1996). Nearly three-quarters of Louisiana NIPF owners enrolled in the Forest Stewardship Program (FSP) ranged from 40 to 69 years old (Lorenzo and Beard 1996). Jacobson (1997) reported the modal subjects of a Florida NIPF study to be between 56 and 75 years old. More than three-quarters of Mississippi NIPF owners who had harvested timber in recent years were found to be at least 50 years of age (Gunter and others 2001). More than two-thirds of minority NIPF landowners in two southeastern Alabama counties were found to be at least 50 years old (Gan and Kollison 1999).

Ownership Reasons and Objectives

Various regional and State surveys of southern NIPF owners have been conducted to determine reasons for ownership and related management objectives. Different surveys, however, have offered different arrays of choices from which single or multiple selections could be made by NIPF owners. Birch (1996), for example, found that the four most popular primary reasons for ownership in the South, accounting for more than two-thirds of all owners and one-third of all private timberland acreage, included residential use, estate use, land investment, and aesthetic enjoyment. Aesthetic enjoyment was the most popular benefit expected in the future decade. The second most popular benefit expected was farm and domestic use (Birch 1996). More than a third of North Carolina NIPF owners indicated that their desire to pass on an estate to heirs was one major reason for owning forest land. Owning forest land as part of a residence and for the enjoyment of owning green space were tied for the second most popular reason (Megalos 2000). The most significant multiple ownership reasons of Virginia NIPF owners included preserving nature (63 percent), maintaining scenic beauty (59 percent), and viewing wildlife (47 percent) (Hodge 1996). Arkansas NIPF landowners included living in a rural environment (58 percent), enjoying green space (54 percent), providing a place for wildlife (54 percent), and creating an estate for heirs (44 percent) as their most popular objectives, selected from a list of 11 choices (Kluender and Walkingstick 2000).

Only 5 to 6 percent of southern private timberland owners were found by Birch (1996) to have an interest in recreation as a primary or secondary reason for ownership. Recreation was also chosen by only 7 percent of all owners as a future expected benefit. Megalos (2000) found that 21 percent of North Carolina landowners favored recreation, such as hunting, camping, fishing, and birdwatching, as one reason for owning forest land. About 40 percent of NIPF owners in Arkansas chose "personal recreation opportunity" as an ownership objective (Kluender and Walkingstick 2000).

Financial returns from timber production and growth in real estate values are important objectives for many forest landowners. Birch (1996) found about 4 percent of southern timberland owners, holding 35 percent of the total private acreage, owned forests primarily for timber production. About 7 percent of all private owners expected to receive income from timber within the following decade. Another 27 percent of all private timberland owners expected land value increase to be a future ownership benefit (Birch 1996).

Timber production was an important ownership objective of almost one-fourth of North Carolina NIPF owners (Megalos 2000). In Virginia, timber production was an important ownership reason for 27 percent of all forest landowners (Hodge 1996). Growing trees for timber to sell was selected as at least one of multiple ownership objectives by a third of Arkansas NIPF owners (Kluender and Walkingstick 2000). Timber production was found by Newman and others (1996) to be the most popular ownership reason chosen by new forest land purchasers in Georgia. This finding could have been influenced by the fact that only owners of tracts of at least 75 acres were surveyed.

Results of a nationwide recreation study, as reported in chapter 11, showed that about 7 percent of southern landowners selected making money as a primary or secondary objective of forest landownership. In Virginia, real estate investment was chosen by 40 percent of forest owners as one important reason for ownership (Hodge 1996). More than half of Arkansas NIPF owners indicated they would "emphasize using land to make money, but will also consider natural aspects" as a future management objective. About 13 percent of these owners included "making money by charging others for hunting, fishing, and other recreation" among their ownership objectives. Only 5 percent of all owners intended to " mostly use land to just make money" (Kluender and Walkingstick 2000).

Ownership reasons and objectives are no doubt greatly influenced by personal beliefs and values. These values, in turn, may be influenced by external factors such as local and regional economies, land management

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traditions, and basic land characteristics. As one moves the focus of a landowner study from regional to substate levels, these factors become more narrowly defined and unique. Several southern researchers have addressed possible differences in various landowner characteristics from this basic perspective. Williams and others (1996), for example, found significant differences between Delta and Southwest Arkansas NIPF owners regarding forest land use preferences. Megalos (2000) found "unequivocal regional differences" in forest landownership objectives among North Carolina landowners. These differences were thought to be related to factors such as historical land use, local timber markets, and site productivity. Mountain region landowners, for example, were more likely to enjoy owning their forests for green space and as a place of residence than landowners in the Piedmont and Coastal Plain regions. Landowners in the Coastal Plains, where farming and forest industry are predominant employers, were found to be focused more on farm and timber-related objectives. Kluender and others (1999) determined that Arkansas NIPF owner groups of different physiographic regions had different management objectives and tendencies. Strong variations were also found among NIPF owners within individual physiographic regions.

Owner Attitudes, Values, and Knowledge

Rural landowners and nonlandowners seem to share similar beliefs and attitudes about forest values and the environment. As reported in chapter 7, Tarrant and others found, with one important exception, no significant differences between these two groups. The exception was that forest landowners were likely to rate wood products as a more important management objective for private forests. The ecological region that people lived in was also found to have had little bearing on beliefs and attitudes.

Some southern forest owners seem to dislike government regulation of private forest use and management, while others think regulation for the public good may become necessary in the future. Related research information, however, is limited. A majority of Arkansas NIPF owners were reported to believe they had the right to use their land in any fashion without regulations, but also believed in environmental protection and land stewardship (Williams and others 1996). More than half of new forest landowners in Georgia, surveyed by Newman and others (1996), indicated land management regulations might be necessary in the future. Another 40 percent felt that private landowners have an obligation to maintain areas for the protection of endangered species. In a study of Mississippi NIPF owners who had harvested timber sometime between 1994 and 1998, Gunter and others (2001) found that the vast majority thought that reforestation should not be regulated by the State government but should remain a landowner decision.

A 1992 survey of residents of the seven States (Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia) revealed that the great majority of survey participants favored a balance between private property rights and environmental regulations, as long as protection of the environment was ensured. Forest owners and nonowners shared similar opinions about this issue (Bliss and others 1994). Differences of opinion among several subgroups were later examined by Bliss and others (1997). Strong majorities of urban and rural residents and forest owners and nonowners agreed that private property rights were important but secondary to environmental protection. Few people of any category agreed that private owners have the right to do as they please with their forests, regardless of environmental consequences. Most private forest owners (63 percent) approved of limiting owner rights if necessary to protect the environment. A majority of private owners also agreed that it would be appropriate for the government to regulate tree cutting on private land to protect streams, wetlands, threatened and endangered species, and scenic beauty.

The attitudes of NIPF owners in the Tennessee Valley who had sold timber in the past differed markedly from other owners who had not. Only 4 out of 10 owners who had sold timber supported limiting private owner rights to protect the environment. Yet only a third of the total believed private owners have the right to do as they please with their forests. These seemingly conflicting findings may suggest that some landowners believe that environmental protection is a personal rather than governmental responsibility. From another perspective, some landowners may feel they should be allowed to tend to their own private business on their land and let others tend to theirs. In a study of South Carolina NIPF owners, for example, Jacobson and others (1996) found that more than half did not agree that the impact of personal land use decisions on neighboring landowners was an appropriate private owner concern. Only 3 out of 10 favored joint planning for land use with neighbors. A study of NIPF owners in nine Southeastern States (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia) revealed a slight majority agreeing that society should regulate landowners' activities, but only if they caused harm to adjacent properties (Brunson and others 1997).

What NIPF owners think is appropriate for private land management may differ from what is thought appropriate for public land. Tennessee Valley landowners were found to share public concerns about clearcutting and prescribed burning on private land, being evenly divided on the acceptability of such practices. Relatively few, however, approved clearcutting and herbicide use on public land (Bliss and others 1994). In a later report, Bliss and others (1997) reported no significant differences between urban and rural residents, or between forest owners and nonowners, in the approval of such practices. Again, it seems that private landowners reflect the general characteristics of the public at large, at least in terms of attitudes toward forest land use and management.

Limited research findings suggest that many landowners may be unaware of the social, political, and environmental policies and issues that influence natural resource conditions and management opportunities in forests. Newman and others (1996), for example, found that most new forest owners in Georgia were unaware of forest management opportunities and laws affecting land management. Most were also unaware of, or uncertain about, the potential use of State Agricultural Preference or Conservation Use classifications to reduce their annual property taxes. In a study of Arkansas NIPF owners, a majority were found unaware of the Endangered Species Act or the Clean Water Act (Williams and others 1996). Jacobson and others (1996) concluded that South Carolina NIPF owners' knowledge of ecosystem management varied widely. Only one-fourth were familiar with the concept. About one-third had no apparent knowledge of it.

Tract size may influence landowner attitudes toward timber production. As reported in chapter 16, various researchers have concluded that the practicality of timber management decreases as tract size decreases. Landowners with the fewest acres are thought to also have the fewest management options to pursue (chapter 15). In a study of Virginia NIPF owners, Hodge (1996) found a significant relationship between ownership of <250 acres and the likelihood that an owner would believe: (1) harvesting has adverse effects on the forest's natural growth process and hunting; (2) cutting firewood is not harvesting trees; and (3) more land was needed, with more trees of higher quality, to harvest timber. Williams and others (1996) found that Arkansas NIPF owners were more likely to practice some type of active forest management when their tracts were >100 acres. This finding is supported by Gunter and others (2001), who found that about two-thirds of Mississippi NIPF owners who reforested their land after a timber harvest owned holdings of at least 100 acres.

Reforestation after timber harvest helps ensure the growth of new stands of desired tree species. Megalos (2000) found that an individual's choice to reforest land was positively associated with variables such as costs, knowledge of cost-share assistance, knowledge of tax incentives, income, and timber prices. Newman and others (1996) reported timber prices to be the most important primary factor justifying reforestation investments by new Georgia owners. Cost sharing and other government payments were strong secondary factors. In a study of Mississippi NIPF owners who had harvested timber between 1994 and 1998, Gunter and others (2001) found that the two leading reasons for reforestation were: (1) the desire to keep land in timber production, and (2) the desire to be good stewards. The two most important owner reasons for not reforesting harvested lands were: (1) the belief that a site would reforest itself naturally, and (2) high reforestation costs.

Private owner attitudes are generally unfavorable toward allowing the public access to their land for recreation. The most important problems and concerns of southern landowners in this respect have included littering and garbage dumping, illegal hunting and fishing, and damage to property fences and gates. About 41 percent have posted their land to control public use and prevent damage (chapter 11). Williams and others (1996) found that major concerns of Arkansas NIPF owners included timber theft, trash dumping, and trespassing.

The percent of individuals who allow public access to their land has been declining over the past 15 years. This change has been due partly to increases in land development pressures, people seeking recreation, and forest fragmentation (chapter 11). Kluender and Walkingstick (2000) found that only 4 percent of Arkansas NIPF owners included providing recreation for others as an important management objective. A study of southern landowners found that most permitted recreation access only to family and friends (chapter 11).

Private Forest Management Planning and Practices

Much research and resource inventory work was focused in past decades on determining the characteristics of southern timber stands and the types of management activities private owners were, or were not, actively practicing. Such information allowed calculations of how many landowners needed timber management information and how much acreage was in need of treatment such as stand improvement or harvest. In more recent years, research information has been gathered about a greater variety of landowner management practices, perhaps reflecting awareness in the forestry community of a greater variety of important ownership objectives.

As noted in chapter 11, the most common management practices employed by southern private landowners included: using fire to control undesirable vegetation (14 percent), wildlife habitat improvement (11 percent), tree planting (10 percent), and mature timber harvest (8 percent). More than 30 percent of landowners had practiced some form of wetlands conservation. Less than a third of large (100+ acre) NIPF landowners in Florida were found to have implemented practices designed to enhance timber growth, improve wildlife habitat, protect water quality, and/or enhance scenic values (English and others 1997). Only 43 percent of FSP participants in the South indicated that water-quality management practices were included in their management plans (Esseks and others 2000). Protection of wetlands proved to be the least frequently used conservation practice of Florida NIPF owners (English and others 1997). Kluender and Walkingstick (2000) reported that past management activities of Arkansas NIPF owners had included wildlife habitat improvement (36 percent), tree thinning (22 percent), tree planting (21 percent), road development (14 percent), and trail development (11 percent).

These findings suggest that numerous private forest landowners in the South are not actively managing their resources. This conclusion is supported by findings of a study of Florida NIPF owners, which determined that 47 percent of them did not actively manage their land. Possible reasons for not managing are acquisition objectives involving land investment, second home sites, and other nonmarket uses (Jacobson 1998). Of course, doing nothing with a tract of forest land can be viewed as an intentional form of passive management. Given the numbers of forest owners throughout the South interested in owning land for nonconsumptive reasons such as green space, aesthetic values, wildlife viewing, etc., doing nothing may be thought to be both practical and cost-effective by many.

Some forest owners may not forgo timber production due to a lack of understanding of management practices and land potentials. Megalos (2000) found, for example, that more than half

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of NIPF owners in North Carolina not interested in timber production either believed their tracts were too small or in too many locations, or they simply did not know where to start. About one-fourth indicated that timber management was just not a personal priority. Nearly one-sixth selected not liking the looks of a harvested area as a reason. Less than one-tenth felt high initial investment costs, government regulations, or other reasons discouraged management. Gan and others (1999) found similar reasons why southeastern Alabama minority NIPF owners were not managing their forest land to improve personal income. These reasons included: lack of capital (44 percent), no time to manage (40 percent), do not know how to manage (38 percent), and have limited knowledge of marketing (29 percent). These owners, however, were very interested in becoming more knowledgeable about various management practices and in timber marketing and selling information (see “Landowner education and technical assistance”).

Even if the millions of private forest owners in the South were all convinced of the need for professional forestry assistance, it would be difficult to estimate how many government and private natural resource professionals would be needed to provide such assistance. The great majority of private owners, however, do not seek professional assistance. Of those people who do seek assistance, many receive it from State agency personnel. Southern State forestry agencies reported providing technical assistance to almost 78,000 landowners in the year 2000. From 1990 to 2000, an average of 76,200 landowners were assisted each year throughout the South (U.S. Department of Agriculture Forest Service 2001). It is not known how many of these owners were new versus repeat customers. Although impressive, such large numbers represent only a small percentage of potential customers. No current information was found about numbers of southern landowners assisted by forest industry and private consulting foresters.

Kluender and Walkingstick (2000) found about three-quarters of Arkansas NIPF owners managed their forests themselves, without any assistance. Among Virginia NIPF owners who had harvested timber, about 46 percent indicated they had not sought any type of professional forestry assistance. The most common reasons included “never thought about it,” “did not know assistance was available,” and “did not know whom to contact” (Hodge 1996).

Tract size seems to be related to whether a landowner seeks management assistance. Hodge (1996) found that the smaller the tract size owned, the less likely an owner would be to seek professional assistance. Among owners who had harvested timber from their land, larger landowners (owning 100 acres or more) were found more likely to seek assistance. Landowner awareness of the potential benefits of good forest management may also be a factor. Hodge (1996) found a significant positive relationship between knowledge and the propensity to seek professional forestry assistance. A similar relationship was found by English and others (1997) between information-seeking activity and participation in the FSP by Tennessee NIPF owners.

In spite of the vast majority of southern forest landowners indicating timber production is neither a primary nor secondary objective, significant percentages of private owners do sell their trees for harvest. The extent to which harvests are conducted for financial gain, lot clearing, interest in sustaining forest ecosystem health, and/or other reasons is unknown. Kluender and others (2000) discovered that about half of Arkansas NIPF owners had sold timber from their land at some time. Birch (1996) found that about 45 percent of all private timberland owners in the South, controlling 78 percent of all private acreage, had harvested timber in the past.

Birch (1996) reported that 1.4 million private owners had intentions to harvest timber on more than 112 million acres of southern timberland within the following decade (1994–2003). Of these owners, <1 percent held tracts >500 acres, but they controlled about 65 percent of the private timberland intended for harvest. Another 18 percent of tracts intended for future harvest ranged in size from 100 to 499 acres (Birch 1996). These findings are supported by the results of a survey of new Georgia forest owners having forest tracts of at least 75 acres. About 60 percent of these owners said they were likely to harvest timber some time in the long-term future (Newman and others 1996).

Amacher and others (1998) reported that owners of large forest tracts were more likely to harvest timber than small tract owners, due to greater concerns about investment risks and returns. Surprisingly, however, more than half of all private owners in the South in 1994 having future harvest intentions held tracts <10 acres. They also accounted for only 1 percent of the total land intended for harvest (Birch 1996). Whether any of the numerous small landowners mentioned actually have had timber harvested from their land by this time, as intended, is not known.

Kluender and others (1999) found that ownership objectives, education, and income levels were strong factors influencing management propensity, inclination to harvest timber, and use of cost-share assistance. In a study of Virginia NIPF owners, however, Conway and others (2000) found significant regional differences in the usefulness of factors such as income and nontimber activity preferences for predicting the probability of timber harvesting.

A professionally prepared forest management plan reflects owner objectives, natural site capabilities, and practices that can be used to achieve desired resource characteristics. In 1994, only 5 percent of all southern private timberland owners had written management plans of some type for their forests. These forests, however, collectively comprised about 40 percent of the South’s total private timberland acreage. Most owners (78 percent) of tracts of at least 5,000 acres did have plans. Plans were found especially uncommon among owners of small and mid-sized tracts (Moulton and Birch 1995). Only 9 percent of corporate NIPF owners had management plans in 1994, representing only 7 percent of the total regional timberland acreage. About 5 percent of individual NIPF owners had management plans. They controlled 14 percent of the South’s private timberland acreage in 1994 (U.S. Department of Agriculture Forest Service 2001). In North Carolina, about 16 percent of NIPF owners had management plans for their forest lands (Megalos 2000).

Melfi and others (1995) found that more than half of the participants in the FSP in South Carolina had management plans prepared by government forestry agency employees. Private consultants had prepared a third of all the Forest Stewardship Program (FSP) plans. Forest industry employees were responsible for the remainder. Individual owners of relatively large tracts were generally found to have had plans prepared by forest industry employees. Owners of smaller tracts generally had their FSP plans prepared by State government personnel.

Land Management Incentives and Disincentives

Taxes—Sampson and DeCoster (1997) reported that influential national and regional forestry leaders believe tax policy rewards to be the most effective motivators for private landowners. McColly (1996) suggested that tax reforms, particularly for inheritance, capital gains, property taxes, and passive loss rules, were the number one concern of NIPF owners throughout the United States.

Since many NIPF owners receive land-based income through infrequent activities such as timber harvesting and land sales, they are viewed as passive investors. Such investors are subject to rules making it difficult to recapture expenses incurred for services such as expert advice or conservation and maintenance measures (DeCoster 1996). Federal tax law provides for the recovery of a percent of invested monies, excluding government cost-share monies, in the form of a tax credit. Provisions also allow early amortization of reforestation and afforestation expenses (Kluender and others 1999). Peters and others (1996) found numerous studies of forest estate cases suggesting that Federal and State estate tax burdens may cause heirs to harvest timber prematurely or abandon timber production activities. Cubbage and others (1993) surmised that high property taxes might lead some landowners to prematurely harvest timber or convert forest lands to more profitable uses, to generate cash needed for tax bills. Peters and others (1996) suggested that expert information and estate planning assistance could save forest land heirs a substantial amount of Federal and State taxes and could help avoid disruptions in management efficiency and continuity. Schelhas (2000) reported that inadequate estate planning was one of the principal obstacles to forest management on minority-owned land. For a detailed discussion of State and Federal tax laws and their influence on forest management activity, see chapter 8.

Private owners have varying opinions about the importance of taxes to forest ownership and management. Newman and others (1996) found that more than half of new Georgia private owners did not consider property taxes to be an important issue. Jacobson (1998) found that only one-fourth of Florida NIPF owners had taken advantage of reforestation tax credits. Megalos (2000) reported <5 percent of North Carolina NIPF owners selected tax-related issues as a management deterrent. More than half of them, however, indicated likely participation in future programs that would reduce property taxes and provide income tax relief. A third also favored the idea of a tax-deferred green investment reforestation account (GIRA) as an incentive. A GIRA, as described by DeCoster (1996), would provide for a tax-free savings account to fund reforestation activities.

Government regulations—For a comprehensive review of State and Federal land and water laws and policies influencing private forest management practices in the South, see the section on Protective Regulatory Policies in chapter 8. The authors conclude that regulatory policies may limit acreage that can be used for certain purposes and otherwise alter landowner management strategies, increase costs, and possibly reduce income. Impacts may vary with tract size, tract resource attributes, location, and owner management objectives. Landowners seeking to maximize income through timber sales, for example, could be more adversely affected than those managing for natural amenity values. Megalos (2000) found, however, that only 7 percent of North Carolina NIPF owners believed government regulations would discourage management.

Government forest management assistance programs—Government technical, educational, and financial forestry assistance programs have been designed over the years to promote certain forest management practices by NIPF owners. Timber production historically has been a primary emphasis of such programs. Perhaps this is one reason why Jacobson and others (1996) concluded that past studies of NIPF owners have usually focused on timber-related issues. Megalos (2000) noted that the strongest justification for government timber-oriented programs might be the nontimber benefits enjoyed by the public, including soil and water-quality protection, scenic beauty, wildlife habitat, carbon sequestration, and recreation. Gaddis (1996) stated that government cost-share incentives program costs are offset by reductions in prices of forest-related goods, such as wood products, as well as public amenities.

The history of Federal-State forestry assistance programs began with the creation of the U.S. Department of Agriculture Division of Forestry in 1898, to assist and educate private landowners (Megalos 2000). Congress passed the first Federal-State cooperative forestry legislation in the Clarke-McNary Act in 1924. This act attempted to slow the rate of timber price increases and forestall a foreseen national timber supply shortage. It provided matching funds to States to supply tree seedlings used for windbreak, shelterbelt, and farm woodlot plantings (Cubbage and Wear 1993).

Gaddis (1996) thoroughly described the history of Federal-State cooperative programs since the 1930s. A summary of this information is presented here. The Agricultural Conservation Program, authorized in 1936, used cost-share monies as incentives for farmers to implement certain soil conservation measures, such as pasture improvement, tree planting, timber stand improvement, and wildlife habitat improvement. In 1956, the first Conservation Reserve Program (CRP) (the Soil Bank) paid farmers to retire farmland from crop production and shared the costs for practices that improved watershed conditions, wildlife habitat, recreation, and aesthetics; controlled soil erosion; and increased wood supplies. The Forestry Incentives Program (FIP) was initiated in 1973 to share the costs of tree planting for timber production. A new CRP was authorized in 1985 to convert highly erodible cropland to pasture or forest. Its primary goals were soil and water conservation and wildlife habitat improvement. These activities were supported by cost-share funds and annual payments to landowners (Gaddis 1996).

In 1990, several new programs were authorized that emphasized forestry practices on private land. In that year, CRP, along with the Wetlands Reserve Program (WRP), was made a part of the Environmental Conservation Acreage Reserve Program (ECARP). Under ECARP, CRP was modified to encourage hardwood tree planting and conversion of grassland to forest. The WRP provided cost-share monies for wetland reforestation (Gaddis 1996).

The FSP and the Stewardship Incentives Program (SIP) were authorized by the Forest Stewardship Act of 1990 to promote management of NIPF tracts of at least 10 acres for multiple objectives, including timber, recreation, wildlife, aesthetics, water-quality and soil conservation. SIP cost-share incentives were designed to replace the timber-oriented FIP incentives. The FSP required a written management plan to be prepared for landowners by State forestry agency personnel or other qualified professionals. SIP cost-share funds were used to help landowners implement approved practices (Gaddis 1996).

Since 1991, a reported 36,786 FSP management plans, covering 8,586,730 acres of NIPF land, have been prepared for southern landowners. In the year 2000 alone, 3,031 plans were prepared, involving 459,864 acres of private forest land (U.S. Department of Agriculture Forest Service 2001).

Esseks and Moulton (2000) reported a profile of the average FSP participant. Participants from the South were predominantly male (85 percent) and white (95 percent), held at least a bachelor's degree (61 percent), and owned from 50 to 199 acres of forest land (36 percent). The median acreage owned was 102 acres. Most did not live on their land (58 percent), had owned it for >10 years (58 percent), and were interested primarily in growing trees and providing wildlife habitat (79 percent). Most had never before received advice about forest land management from a specialist (58 percent), had had someone from a public agency prepare their FSP plan (70 percent), and had received follow-up assistance (72 percent), primarily from a State agency (80 percent). Participants' annual incomes ranged from <$25,000 (10 percent) to >$75,000 (30 percent). Their median income was between $50,000 and $75,000 per year.

Eight Southern States currently have their own forestry incentives programs. In 1970, Virginia led the way with the creation of its Reforestation of Forest Lands program. This program provides cost-share funds to private landowners to support reforestation, site preparation, timber stand improvement, firebreak construction, prescribed burning, and fencing. Other Southern States with forestry incentives programs include Alabama, Florida, Kentucky, Louisiana, Mississippi, North Carolina, and Texas (Megalos 2000).

Landowner use of cost sharing— Cost-share programs are very popular with landowners because they reduce initial investment costs for various forestry practices and increase rates of financial return (Kluender and others 1999). Studies designed to determine whether cost-share monies take the place of other available capital have had mixed results. In a review of related research, Gaddis (1996) found that some researchers did find evidence of cost-share fund substitution for available capital, while others did not. Kluender and others (1999) found that Arkansas cost-share users with timber management interests would probably have pursued tree growing and commercial forestry activities regardless of assistance payments. Esseks and others (2000), however, found that 60 percent of southern FSP participants would not have accomplished as much management plan implementation if they had not received cost-share payments. Only one-fourth would have implemented their plans without cost-share funds.

As mentioned earlier, Newman and others (1996) reported that cost sharing and other government payments were strong secondary factors influencing reforestation activities. Williams and others (1996) noted that Arkansas NIPF owners have historically reforested a large portion of their harvested land only during periods of government incentives programs. Megalos (2000), however, found that only one-third of North Carolina forest owners favored future cost-share funding assistance for tree planting and timber management. Reasons for this were not requested from, or provided by, the landowners. Gunter and others (2001) found that a large number (44 percent) of NIPF owners in Mississippi had used government cost-share funds to help cover their reforestation expenses.

Kluender and others (1999) reported that NIPF owners in Arkansas who owned land primarily for wildlife, water, and natural beauty were not likely to be users of government cost-share incentives. Incentives users were found to most likely own land primarily for growing trees and to use or lease their land for hunting. Somewhat similar results in part were reported by Melfi (1998), who found that 60 percent of FSP participants in South Carolina had timber management as a primary objective, while 28 percent had wildlife management as a primary objective.

Predicting cost-share use is difficult. Kluender and others (1999) found that cost-share users, on average, were better educated and had higher income levels than nonusers. Megalos (2000), however, found annual income and education levels were not significant predictors of forest owner participation in North Carolina's forestry cost-share program. In addition, a study of Louisiana NIPF owners found that, although 89 percent of SIP cost-share users had either completed college or had some college education, no significant positive relationships existed between educational levels and cost-share use (Lorenzo and others 1996).

Tract size seems to be a predictor of cost-share program participation. Both Megalos (2000) and Lorenzo and others (1996) found significant positive relationships between the likelihood of cost-share fund use and relatively large forest acreage ownership and tract size. Jacobson (1998) found that 43 percent of Florida NIPF owners of tracts >20 acres in size had participated in cost-share programs.

Megalos (2000) found that gender was not significantly related to North Carolina NIPF owner cost-share use. Resident landowners were less likely to participate than nonresidents. Not surprisingly, landowner awareness of program assistance was found to be the most important predictor of participation. Other than for individuals in the finance, real estate, and insurance professions, owner occupation was not a significant predictor of cost-share use. Lorenzo and others (1996) also found that NIPF owner occupation was not significantly associated with cost-share use in Arkansas.

Significant regional (substate) differences were found among private landowners in North Carolina concerning likelihood of participation in forestry incentives programs (Megalos 2000). These programs involved income tax relief, property tax relief, cost sharing, low-interest loans, and educational and technical assistance activities.

Landowner education and technical assistance—Educational programs help landowners understand forestry opportunities and provide incentives for undertaking various management practices. McColly (1996) suggested that education was the second most important issue for NIPF owners, following tax reform. Numerous Federal and State agencies, universities, private forest industries, and other groups are involved in educational efforts of various kinds. Their messages and objectives differ. A report on nationwide non-Federal forest management opportunities noted the importance of Federal–non-Federal partnerships in educational outreach and program delivery (National Research Council 1998).

When asked to rank their interest in various educational and technical assistance program topics, Florida NIPF owners indicated that information about property rights and regulations was very important. Timber prices and taxes were the next most important topics. Megalos (2000) found that educational programs which provided better timber price information would be popular with nearly half of North Carolina private forest owners.

Within a specific forest owner group, subgroups may have differing educational preferences. Jacobson (1998), for example, found that Florida absentee NIPF owners owning <100 acres were most interested in recreation and wildlife habitat. They also preferred to attend educational meetings on weekends. The larger landowners (500+ acres) were more interested in receiving information through workshops. Absentee landowners as a whole indicated they would rather receive information through publications than attend meetings. Meetings held in the city in the evening were preferred over meetings held during the day in the woods.

Gunter and others (2001) reported that a majority of Mississippi NIPF owners who had harvested timber in recent years had not participated in landowner educational programs. Of those who had participated, the likelihood that they reforested land was significantly related to a higher rate of educational program participation.

Most minority NIPF owners in a two-county area of southeastern Alabama were found willing to participate in continuing education programs to improve their knowledge and skills in forest management (Gan and Kollison 1999). Megalos (2000) found that less than a third of North Carolina NIPF owners would be interested in participating in future programs involving educational demonstrations and tours. Gunter and others (2001) reported that a majority of NIPF owners in Mississippi believed the most important sources of basic forestry information were books, bulletins, and newsletters. Only one-fourth indicated that meetings and short courses and were highly important sources of information. The same finding held true for the importance of receiving information from any individual a gency or professional organization.

Although technical advice and assistance provided by professional natural resource managers can be assumed to be important influences on landowner management activity, related research information is scarce. One study found that technical assistance was thought by most (71 percent) southern FSP participants to be a very important factor positively influencing FSP plan implementation (Esseks and others 2000). A large percentage (68 percent) of Florida NIPF owners were found by Jacobson (1998) to have received technical assistance, primarily from State forestry agency personnel. More than half of Mississippi NIPF owners who had reforested their land after harvest felt that the advice of a professional forester was highly important. Of those who had not undertaken reforestation, only one-fourth had sought advice about reforestation from a professional forester (Gunter and others 2001). About two-thirds of minority NIPF owners in a two-county area in Alabama were found to have received past forest management or marketing assistance from forest industries, the extension service, consulting foresters, or State forestry professionals (Gan and Kollison 1999). Of NIPF owners in Mississippi who had received professional assistance, most were found to believe that the services of consulting foresters and State forestry agency foresters were most useful (Gunter and others 2001).

Bliss and others (1997) suggest that future southern foresters will need to be competent in assessing and prescribing management practices appropriate for a diversity of forest resource values. Future professionals will need a more explicitly environmental orientation in all aspects of the profession, from undergraduate education to continuing education (Bliss and others 1997). A key conclusion of Megalos (2000) was that alternatives to traditional timber-oriented management plans were needed to cater to the diverse ownership objectives of North Carolina NIPF owners.

Discussion and Conclusions

About 89 percent of the South's timberlands are privately owned. A majority is owned by individuals and family units. These owners form a core ownership group commonly referred to NIPF owners. Collectively, individual NIPF owners represent about 95 percent of all private timberland owners and control about 63 percent of the South's total private timberland acreage. Most own just one tract of timberland and live either on or within a mile of that tract.

The number of private timberland owners in the South is growing, and the average tract size is shrinking. This parcelization of timberland will influence how private forests can and will be managed for various purposes. Most private timberland owners have tracts <10 acres. These owners, however, account for only 4 percent of the total acreage. Private owners holding tracts >500 acres, representing <1 percent of all private owners, control almost 47 percent of the South's private timberlands.

The size of a tract, as well as the sizes and characteristics of adjacent tracts, can limit an owner's options for certain uses and management benefits. Small tracts of forest land, for example, may not produce the volumes of wood fiber needed to interest timber buyers. They may also not provide the acreage required for habitat and range by some wildlife game species or needed for certain outdoor recreation activities. But small tracts obviously have values and produce benefits that land purchasers desire.

Available research information does not allow the description of the average private southern forest landowner. Factors that influence the ways in which owners manage their land include income, personal values, tract size, residence, long-term plans, knowledge of alternative management options and benefits, taxation policies, and government assistance programs. Other likely factors may include historic land use, soil productivity, local markets for resource goods and values, and current land and resource health.

Perhaps because of popular concerns about timber management activity and future supplies of wood fiber, much research during the past decade has focused on timber growing by NIPF owners. In attempts to define owner characteristics and predict management behavior, different researchers have also collected somewhat varying types of owner-related data. This variation makes it difficult to derive information useful for the South as a whole. The often conflicting results of both individual State and Southwide studies simply suggests that, as for the public in general, landowners with similar backgrounds facing similar choices often have different objectives and make different management decisions.

Research findings lead to some very broad conclusions about southern NIPF owners. More than half of them are white-collar workers and retirees, probably 50 to 60 years old, with varying income and education characteristics. Most own forest land because they want to reside in a rural area, see their land investment grow in value, use the land for farm or domestic reasons, enjoy the natural resources, and/or have an estate to pass along to heirs. Most probably manage their land themselves. Many seem to be somewhat interested in making money from land investments, but they are also interested in wildlife, water, aesthetics, and other natural values and benefits. Many, especially those who are relatively new owners or small tract owners, have limited knowledge about forest management practices, current environmental laws, and the concept of management for renewable, sustainable resource benefits. Nearly half, holding more than three-quarters of the total timberland acreage in the South, have harvested timber in the past, while many intend to do so in the future. It is unclear what other kinds of management activities they will undertake. There are indications that some may plant and periodically thin trees, implement wildlife habitat improvement measures, or actively attempt to conserve natural resources in some manner.

The reasons why certain forest owners are motivated to implement certain practices and others are not probably reflect basic resource characteristics, personal values and attitudes, and available income. A change in any of these factors—whether due to personal fortune or misfortune, the results of past management practices, new information, expert technical assistance, tax relief, or government cost sharing—would likely influence a change in an owner's objectives.

Rural landowners and nonlandowners seem to have similar beliefs and attitudes about forest values. Private forest owners, as well as nonowners, from both rural and urban backgrounds, share strong concerns about the need for environmental protection. Many feel they have a personal obligation to protect the quality of resources under their care without interference from the government or neighboring landowners.

Most southern landowners are not interested in allowing the public to use their property for outdoor recreation. Many have concerns about trespassing, garbage dumping, and timber theft. Very few, especially those with small to mid-sized tracts, have written management plans to guide them in achieving their objectives. They also generally do not take advantage of free government forestry assistance and financial incentives programs. In fact, an average of <2 percent of all southern forest owners receive technical assistance each year from State forestry agencies. It is not known how many seek and receive assistance from other public and private agencies and individual consultants, who are important sources of assistance. It seems that many owners may not be aware of available assistance, think that management activities are too costly or complicated, or view forestry program assistance as being focused mostly on timber production and harvest-related objectives.

Research findings commonly describe wide variations in certain NIPF owner characteristics, intentions, and behaviors between substate regions and even within such regions. This variation suggests the difficulty in describing, as well as understanding or predicting, different management objectives and behaviors for NIPF owner groups in the South. Many NIPF owners who have timber production and income as primary ownership objectives probably have wildlife-oriented recreation use as a secondary objective. Although they represent a relatively small percentage of all landowners, these timber-oriented owners make management decisions for more than one-third of all private timberland in the South. Many of them own at least 100 acres of land, which is thought by some to be the minimum size needed for profitable timber production. They are the most likely to be aware of government forestry programs, participate in government cost-share incentives activities, seek professional assistance, have management plans, and be somewhat knowledgeable about forestry operations.

Considerable research information is available about the motivations and behavior of participants in government cost-share incentives programs and the FSP. Disagreements exist about the relative merits of these programs. It is certain, however, that cost-share incentives are popular with owners who must invest monies to realize long-term financial returns. Management activity costs, knowledge of available assistance, State and Federal tax policies, personal income, available capital, and resource commodity sale values are other important motivational factors. When nonmonetary returns are more important, it seems that the primary force influencing forest resource management may be a desire to protect and maintain natural resources to ensure continued benefits not only for personal reasons, but also for intrinsic environmental health-related purposes.

Little is known about the management objectives and motivations of NIPF corporations, partnerships, clubs, and other entities, which own a significant 11 percent of all private timberland in the South. TIMOs, which control about 4 million acres of timberland throughout the South, are assumed to be oriented toward management activities that generate investment profits.

The decisions of all private forest owners in the South, with all their diverse interests and objectives, collectively affect the health and use of vast natural resources of significant public interest. Government and private programs that focus on the objectives of a single owner group will miss opportunities to encourage and support the production of diverse benefits valued by a public having diverse interests and needs. More landowners might be receptive to such encouragement if they understood forestry and forest management to be means of securing a variety of forest resource benefits, rather than just those associated with the production of valuable commercial timber supplies. On the other hand, the numbers of landowners that government and private forestry professionals are able to assist on a one-to-one basis will no doubt continue to represent a relatively small percentage of a huge owner population. Understanding the specific needs and interests of different targeted owner subgroups will remain critical to developing programs that successfully deliver useful assistance. In this respect, primary reasons for ownership and ownership objectives will remain the most important types of research information needed. State-level research, especially for owner subgroups within individual States and substate regions, will likely provide much more accurate program planning information than that generated by regional studies.

Needs for Additional Research

- Identify the technical information and professional assistance needs of NIPF owners having nontimber-related interests and management objectives, for individual States.
- Identify the interests, management activities, and objectives of private owner subgroups such as Native Americans, African-Americans, White Americans, Asian-Pacific Americans, Hispanic Americans, women, and men.
- Identify the skills and educational curricula needed to produce a future generation of professional natural resource managers and leaders able to provide the special types of information and technical assistance needed by diverse landowners.
- Identify the potential social and economic benefits of providing targeted information and technical assistance to meet the needs and objectives of nonindustrial private corporation owners.
- Identify the nature, extent, and effectiveness of forestry-related educational and technical assistance activities of public and private agencies.

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Literature Cited

Amacher, Greg; Conway, Christine; Sullivan, Jay; Hensyl, Curt. 1998. Effects of shifting populations and preferences on the behavior of nonindustrial landowners and forest industry: empirical evidence from Virginia. SOFAC Rep. 12. The Southern Forest Resource Assessment Consortium. 106 p.

Birch, Thomas W. 1996. Private forest land owners of the Southern United States, 1994. Resour. Bull. NE–138. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 195 p.

Bliss, J.C.; Nepal, S.K.; Brooks, R.T., Jr.; Larsen, M.D. 1994. Forestry community or grandfalloon? Journal of Forestry. 92(9): 6–10.

Bliss, John C.; Nepal, Sunil K.; Brooks, Robert T., Jr.; Larsen, Max D. 1997. In the mainstream: environmental attitudes of Midsouth forest owners. Journal of Forestry. 21(1): 37–43.

Brunson, Mark W.; Yarrow, Deborah T.; Roberts, Scott D. [and others]. 1997. Nonindustrial private forest owners and ecosystem management: can they work together? Journal of Forestry. 94(6): 14–21.

Cleaves, D.A.; Bennett, M. 1994. Holding size and behavior of nonindustrial private landowners: a cautious second look. In: Newman, D.H.; Aronow, M.E., eds. Forest economics on the edge: Proceedings of the 24th annual southern forest economics workshop. Athens, GA: The University of Georgia, Daniel B. Warnell School of Forest Resources: 196-209.

Cubbage, F.W.; Wear, D.N. 1993. Can nonindustrial private forest land owners make up the shortfall in timber production from national forests? In: Proceedings of the 1993 Society of American Foresters national convention. Bethesda, MD: Society of American Foresters: 421–426.

Cubbage, Frederick W.; New, Barry D.; Moulton, Robert J. 1996. Evaluations of technical assistance programs for nonindustrial private forest land owners. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 367–376.

Cubbage, Frederick W.; O'Laughlin, Jay; Bullock, Charles S., III. 1993. Forest resource policy. New York: John Wiley. 562 p.

Day, Jennifer C.; Cury, Andrea E. 1998. Current population reports, P20–513, educational attainment in the United States. Update. Washington, DC: U.S. Bureau of the Census; U.S. Government Printing Office. 1 p.

SOCIAL

DeCoster, Lester A. 1996. Green IRAs to improve forest care. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 300–307.

de Steiguer, J.E. 1984. Impact of cost-share programs on private reforestation investment. Forest Science. 30(3): 697–704.

Doolittle, L.; Straka, T.J. 1987. Regeneration following harvest on nonindustrial private pine sites in the South: a diffusion of innovations perspective. Southern Journal of Applied Forestry. 11(1): 37–41.

English, Burton C.; Bell, Caroline D.; Wells, Garland R.; Roberts, Roland K. 1997. Stewardship incentives in forestry: participation factors in Florida. Southern Journal of Applied Forestry. 21(1): 5–10.

Esseks, J. Dixon; Moulton, Robert J. 2000. Evaluating the forest stewardship program through a national survey of participating forest land owners. DeKalb, IL: Northern Illinois University, The Center f or Governmental Studies, Social Science Research Institute. 113 p.

Franklin, E.C. 1990. N.C. forest land owners survey results. Res. Sum. Raleigh, NC: North Carolina State University, Small Woodlot Program. [Number of pages unknown].

Gaddis, Deborah A. 1996. Accomplishments and program evaluations of forestry financial assistance programs. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 357–366.

Gan, Jianbang; Kollison, Stephen H., Jr. 1999. Minority forest land owners in southeastern Alabama. Southern Journal of Applied Forestry. 23(3): 175–178.

Greene, John L. 1996. The effect of income tax incentives on cash flows from nonindustrial private forests. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 308–317.

Gunter, J.E.; Bullard, S.H.; Doolittle, M.L.; Aranao, K.G. 2001. Reforestation of harvested timberlands in Mississippi: behavior and attitudes of nonindustrial, private forest landowners. Bull. FO172. Mississippi State, MS: Mississippi State University, Forest and Wildlife Research Center. 25 p.

Hodge, Sandra S. 1996. Challenges for ecosystem management with Virginia NIPF owners. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 426–433.

Jacobson, Michael G. 1998. Developing extension programs for private forest land owners in the Southeast: are we putting the cart before the horse? In: Extension forestry: bridging the gap between research and application; third IUFRO extension working party symposium. http://iufro.boku.ac.at/iufro/iufronet/d6/wu60603/proc1998/jacobson.htm. [Date accessed unknown].

Jacobson, Michael; Jones, Edwin; Cubbage, Fred. 1996. Landowner attitudes toward landscape-level management. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 417–425.

Kluender, R.A.; Walkingstick, T.L. 2000. Rethinking how nonindustrial landowners view their lands. Southern Journal of Applied Forestry. 24(3): 150–158.

Kluender, R.A.; Walkingstick, T.L.; Pickett, J.C. 1999. The use of forestry incentives by nonindustrial forest landowner groups: is it time for a reassessment of where we spend our tax dollars? Natural Resources Journal. 39: 799–818.

Kurtz, W.B.; Noweg, T.A.; Moulton, R.J.; Allig, R.J. 1996. Retention, condition, and land-use aspects of tree plantings under Federal forest programs. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 348–356.

Lorenzo, Alfredo B.; Beard, Pat. 1996. Factors affecting the decisions of NIPF owners to use assistance programs. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 264–275.

McColly, Robert. 1996. Consulting foresters perspective. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 34–36.

Megalos, Mark A. 2000. North Carolina landowner responsiveness to forestry incentives. Raleigh, NC: North Carolina State University. 119 p. Ph.D. dissertation.

Melfi, Frances M.; Straka, Thomas J.; Baumann, Jeffrey L.; Marsinko, Allan P. 1995. An analysis of nonindustrial private forest land owners' attitudes towards the forest stewardship program. In: Caulfied, Jon P.; Bullard, Steven H., eds. A World of forestry: Proceedings of the 25th annual southern forest economics workshop. Mississippi State, MS: Mississippi State University, Department of Forestry: 90-105.

Moulton, Robert J.; Birch, Thomas W. 1995. Southern private forest land owners—a profile. Forest Farmer Magazine. September/October: 44–46.

Munn, Ian. 1996. Public, private, expert, layman: who's selling makes a difference. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 386–393.

Nagubadi, V.; McNamara, K.T.; Hoover, W.L.; Mills, W.L., Jr. 1996. Program participation behavior of nonindustrial forest land owners: a probit analysis. Journal of Agriculture & Applied Economics. 28(2): 323–336.

National Research Council. 1998. Forested landscapes in perspective: prospects and opportunities for sustainable management of America's non-Federal forests. Washington, DC: National Academy Press. 249 p.

New, Barry D. 1995. The stewardship incentives program, 1992–1994: a review of accomplishments. Raleigh, NC: North Carolina State University. 37 p. M.S. thesis.

Newman, David H.; Aronow, Mary Ellen; Harris, Thomas G., Jr.; Macheski, Ginger. 1996. Changes in forest land ownership characteristics in Georgia. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 214–221.

Peters, Daniel M.; Haney, Harry L., Jr.; Greene, John L. 1996. Effects of Federal-State death and gift taxes on the management of private nonindustrial forest lands for selected States. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 285–299.

Royer, J.P. 1987. Determinants of reforestation behavior among southern landowners. Forest Science. 33(3): 654–667.

Royer, Jack P.; Moulton, Robert J. 1987. Reforestation incentives: tax incentives and cost-sharing in the South. Journal of Forestry. 85(8): 45–47.

Sampson, R. Neil; DeCoster, Lester A. 1997. Public programs for private forestry. Washington, DC: American Forests. 100 p.

Schelhas, John. 2000. Sustainability and forest fragmentation in the U.S. South: minority and limited resource landowners. In: DeCoster, Lester A., ed. Fragmentation 2000: a conference on sustaining private forests. Alexandria, VA: Sampson Group, Inc.: 154-159.

Sinclair, K.D.; Knuth, B.A. 2000. Nonindustrial private forest landowner use of geographic data: a precondition for ecosystem-based management. Society and Natural Resources. 13: 521–526.

Teasley, R. Jeff; Bergstrom, John C.; Cordell, H. Ken [and others]. 1999. Private lands and outdoor recreation in the United States. In: Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 183–218.

Tyson, C. Benjamin; Broderick, Stephen H.; Snyder, Leslie B. 1998. A social marketing approach to landowner education. Journal of Forestry. February: 34–40.

U.S. Department of Agriculture, Forest Service. 2001a. Selected annual State forestry agency program accomplishment report data. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry. [Number of pages unknown].

U.S. Department of Agriculture, Forest Service. 2001b. Selected forest inventory analysis data. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry. [Number of pages unknown].

Williams, Richard A.; Voth, Donald E.; Hitt, Carl. 1996. Arkansas' NIPF landowners' opinions and attitudes regarding management and use of forested property. In: Baughman, M.J., ed. Proceedings: symposium on nonindustrial private forests: learning from the past, prospects for the future. St. Paul, MN: University of Minnesota, Minnesota Extension Service, Extension Special Programs: 230–237.

Chapter 10: Local Economic Impacts of Forests

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Key Findings

■ The overall southern economy has grown since 1969, with total jobs increasing by an average of 2.6 percent per year since 1969. Manufacturing jobs increased by only 0.8 percent per year and agricultural jobs by only 0.1 percent per year. Poverty and unemployment have decreased in the South, but are still higher than in the United States as a whole.

■ In 1997, timber and agriculture, along with subsequent processing, directly contributed approximately 6 percent of jobs and gross regional product (GRP) in the South. Wood products sectors contributed 1.93 percent of jobs, and agriculture sectors contributed 4.27 percent of jobs. Wood products accounted for 2.31 percent of GRP, and agriculture 3.54 percent.

■ The U.S. wood products industry continues to concentrate in the South, which has 39.3 percent of U.S. wood products jobs. Both lumber/wood products and pulp/paper concentration increased, while the furniture sector concentration decreased. The percentages of State-level jobs and income in wood products have generally declined since 1969. Actual numbers of jobs have remained fairly constant.

■ Tourism-related industries are increasing in the South, but are not becoming more concentrated in the South. The percentage of State-level jobs and income in the tourism-related sectors is increasing in all 13 States, as are the actual numbers of jobs and amount of income.

■ In 1997, wood products sectors contributed 5.5 percent of southern jobs and 6 percent of GRP. Public lands represented 8.5 percent of this contribution.

■ In 1997, outdoor recreation-based tourism contributed between 0.64 and 2.88 percent of southern jobs and between 0.51 and 2.51 percent of GRP. Public lands represented approximately 56 percent of this contribution.

■ National forests contributed 1.7 percent of the value of timber harvested and an estimated 17 percent of outdoor recreation-based tourism in 1997. The USDA Forest Service contributed more than $330 million to the southern economy for management of the national forests, research and development, State and private forestry, and payments to States.

■ National forests in the Southern Region are the second most heavily used of the nine USDA Forest Service regions with visits of 1.9 per acre, reflecting the scarcity of public land for outdoor recreation in this region.

■ Fourteen southern counties have high concentrations of wood products employment and high percentages of land managed by the USDA Forest Service.

Introduction

Economic Growth, Diversity, and Dependency

The economy of the South has grown in proportion to the growth in population and in concert with changes in the national economy. From a primarily agrarian economy in 1850, the South became a center for U.S. manufacturing. More recent growth has focused on the service and technology sectors, increasing the diversity of the southern economy. Through all these developments, the South's forests have provided raw materials for wood products industries as well as beauty and recreational opportunities for an increasingly wealthy population.

The South remains largely rural, with higher poverty and lower income than more urbanized regions (Cook and Mizer 1994, Ghelfi 2001, Gibbs 2001). Some areas are still highly dependent on a single industry, including timber, lumber, furniture, and pulp and paper. According to Gale and McGranahan (2001) and Gibbs (2001), many rural areas are still part of the old economy based on manufacturing and resource extraction. Recent growth in southern rural areas was led by industrial machinery and equipment manufacturing, followed by food and then wood processing (Gale and McGranahan 2001). This contrasts with urban areas, where consumer and producer services led recent growth.

Recent forest assessments in the South include two subregional assessments completed for the two mountain regions, the Southern Appalachians (Southern Appalachian Man and the Biosphere 1996) and the Ozark-Ouachita Highlands (U.S. Department of Agriculture, Forest Service 1999). The most recent Southwide assessment was "The South's Fourth Forest" (U.S. Department of Agriculture, Forest Service 1988), which covered essentially the same region as the current Assessment but

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focused nearly exclusively on the wood products sectors. The two subregional assessments concluded that wood products were important but not dominant and that populations and income were increasing, leading to increased demand for recreational services. Manufacturing and farming were still significant aspects of local economies, but were declining in importance. "The South's Fourth Forest" noted that "timber is usually considered the most important [sector] in economic terms" (U.S. Department of Agriculture, Forest Service 1988, p. 10). The national forests were reported to have contributed over $124 million to the local economy but accounted for only 6 percent of regional forest land.

Recreation and timber are the primary forest-based economic sectors today, and this chapter focuses on the roles of these two sectors in the southern economy. Other important contributions of forests to the quality of life are addressed in chapter 12. Wood products industries include timber production on both public and private land and the subsequent harvesting and processing into wood, furniture, or paper products. Recreation and tourism in forests includes camping, hiking, sightseeing, hunting, fishing, biking, and other activities. The economic impacts of these activities are measured in terms of the expenditure by each person for each day of activity.

Conceptual Model

A study of the sustainability of southern forests requires an understanding of the interactions between local communities and the forests around them. Forests influence the economy of a community, State, or region both directly and indirectly. Direct influences of forests include providing raw materials for use in production (timber and forage), as well as providing locations for numerous outdoor activities such as recreation, fishing, and hunting.

Indirect influences include contributions to environmental services such as carbon storage, shading, water filtration, and erosion control. Indirect effects may also include the amenity value of the forested landscape to nonusers, thereby encouraging migration and development (Cromartie 2001, Nord and Cromartie 1997). Several recent studies have shown the importance of amenities, and the recreation/tourism that derives from them, as drivers of the economy, leading to economic growth (Beale and Johnson 1998, Deller and others 2001, English and others 2000, Marcouiller 1998).

The ownership of forest land provides income to landowners as a return to capital through harvesting, or through selling the land, or possibly through hunting leases. In this chapter, we primarily address the effects on jobs and income from direct influences. To capture some of the indirect influences, we address the overall economy, including size, make-up, poverty, migration, and unemployment. Chapter 11 (recreation) and chapter 12 (quality of life) address other aspects of the relationship between communities and forests.

Methods

The Assessment region consists of the 13 Southern States, covering 583 million acres with a 2000 population of 91,776,331. The region represents 24 percent of the U.S. area and nearly 33 percent of the U.S. population. Division of the region into subregions is important for understanding and displaying the data. States were chosen and are used in the remainder of this chapter, because State laws and policies influence overall and sector-specific economic growth. Methods include time trends, means, correlation coefficients, average annual percent change, and an input-output model, IMPLAN. With the exception of the IMPLAN model, techniques can be found in any basic statistics textbook.

IMPLAN was developed to analyze impacts of forest plan alternatives on the national forests. It is currently maintained by the Minnesota Implan Group, Inc., in Stillwater, MN (1997). The model evaluates the effects of a change in demand for a good or service, taking into account imports to and exports from a region, local production efficiency, and spending by households. IMPLAN also includes transfer payments to and from governments and households, including pensions, welfare, and taxes. Thus, the model includes spending by retirees, the unemployed, and the reduction in local income due to taxation.

For this analysis, supply and demand were pooled to estimate trade. This method assumes that local purchases of a commodity are purchased from local suppliers, to the extent possible, with excess purchases imported from outside the region. Supply/demand pooling results in larger multipliers than the alternative method (regional purchase coefficients). In our opinion, however, this method is more representative of actual southern trade flows for the forest-based sectors. Because we are modeling the entire South, larger multipliers are of less concern than if we were modeling only a small subregion.

For the IMPLAN analysis, the nonforested portions of Texas and Oklahoma were excluded, and the remainder of the South was treated as one region. Analysis of one large region resulted in larger multipliers, and, thus, larger economic impacts, than would result if smaller regions were used. Multipliers for the wood products sectors were previously developed for each State by Aruna and others (1997), also using IMPLAN.

Input-output models are based on a description of the economy as an interrelated system of equations, where output of each commodity or service is the sum of demands from households (final demand) plus demands from all industries or services that use the commodity for further processing (intermediate demand). Inputs into production include labor (jobs and income), capital (inventories, property, and proprietor income), and cost of materials. The values of inputs of labor and capital sum to value added, and value added minus indirect business taxes is the value of gross industry production. When summed for a State, region, or Nation, this value is gross State, regional, or national product, our most commonly used measure of general economic welfare.

Input-output models do not provide a complete evaluation of the links between the economy and well-being. However, they do provide insights into one important dimension of this relationship—the link between forests and jobs and income. Other aspects of well-being are addressed in chapters 11 and 12. Many of the limitations of input-output modeling, including fixed production technology, fixed factor prices, and no supply constraints, are not at issue in this analysis because we did not use IMPLAN to predict the effects of changes in final demand on the economy. We used the model to describe the state of the economy in 1997, using production relationships, prices, quantities, and incomes from 1997.

Analyses of the contribution of forests to local economies, particularly comparisons between wood products and recreation/tourism, are complicated by the determination of the actual user of the forest or forest product. The user of timber would be a logging contractor, who is the first, though not the last, user of the timber produced in the South. The user of forest-based recreation is the consumer, who is the end user of such services. Thus, the impact of timber includes the effect of growing and logging timber, and may also include subsequent processing by sawmills, pulpmills, other mills, and furniture manufacturers. The analyses presented below allow the reader to assess the impacts through mill processing, or to stop at any earlier processing stage. Recreation impacts were developed for both resident and nonresident users, where residents were defined as those recreating within 50 miles of home.

Data Sources

The primary sources of data included county- and State-level estimates of jobs and income developed by the Regional Economic Information System (REIS) of the Bureau of Economic Analysis, U.S. Department of Commerce (1999), and data from the Economic Census of 1997 (U.S. Department of Commerce, Bureau of the Census 2000b). This information was also used in the IMPLAN database for 1997, from which economic impacts were developed for this chapter. Also used in the IMPLAN database were data from the Economic Census, the Bureau of Labor Statistics, and County Business Patterns (see Minnesota IMPLAN Group 1997 for further information on this database). The Bureau of Labor Statistics provided the unemployment and wage data (U.S. Department of Labor, Bureau of Labor Statistics 2000), and the Census Bureau was the source of the poverty information (U.S. Department of Commerce, Bureau of the Census 2000a, 2001, 2002).

Sectors examined included wood products and recreation/tourism. The wood products sector includes Standard Industrial Codes (SIC) 24 (lumber and wood products), 25 (furniture), and 26 (pulp and paper). Data from the Economic Census and IMPLAN for SIC 24 were adjusted to exclude mobile homes, while data from REIS were not adjusted as this information was not available. Also included in the IMPLAN analyses were the timber producing sectors which were not included in the Economic Census or REIS data.

For the time-series examination of the recreation/tourism sector (which we will subsequently refer to as the tourism-related sectors) we included SIC 58 (eating and drinking places) and SIC 70 (hotels and lodging). In the impact analysis for 1997, we used three different methods to define the extent of the outdoor recreation or forest-based tourism sectors. These data derived from the National Survey on Recreation and the Environment (NSRE) (Personal communication. 2001. Ken Cordell, Project Leader, Forestry Sciences Laboratory, Southern Research Station, 320 Green Street, Athens, GA 30602-2044), the Travel Industry Association of America (TIA) (1999), and the Tourism and Travel Satellite Accounts (TTSA) (Kass and Okuba 2000).

Results

The Southern Economy

Growth and change—As in the United States as a whole, the economy in the South has grown nearly continuously since World War II. Growth in jobs and income exceeded growth in population (2.6 percent per year versus 1.6 percent per year between 1969 and 1997). Manufacturing industries were a major driver of the southern economy during this period, with the proportion of U.S. manufacturing jobs in the South increasing from 23 percent in 1969 to 29 percent in 1998 (fig. 10.1).

Manufacturing wages and salaries rose from 19 to 27 percent of the national total in 30 years (fig. 10.1). Having 29 percent of the jobs, but only 27 percent of the salaries supports the notion that the South has a large, inexpensive labor force. Nevertheless, average hourly

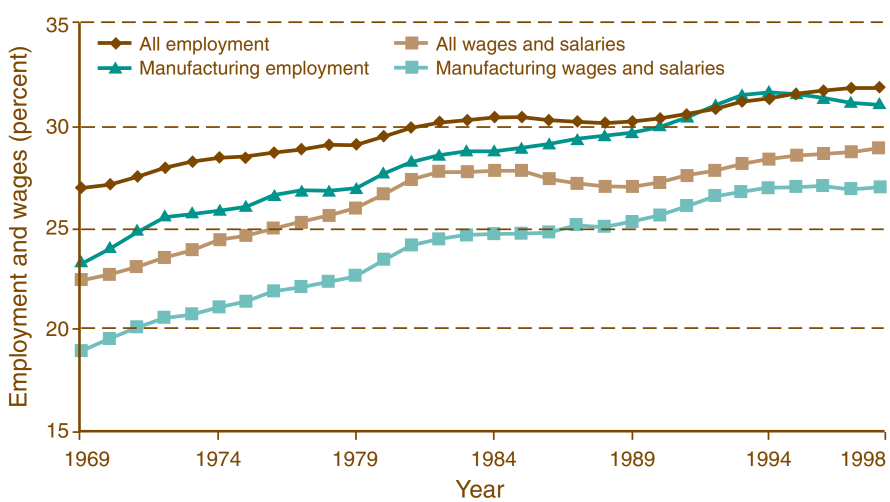

Figure 10.1—Percent of U.S. employment and wages in the South, 1969 to 1998.

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manufacturing wages have increased in all Southern States since the mid-1970s. In 1999, Louisiana had the highest average hourly wage ($15.19), followed by Kentucky ($14.26) and Oklahoma ($12.69). The lowest average hourly wages were in South Carolina ($10.67), Mississippi ($11.18), and Arkansas ($11.55).

Figure 10.2 shows the average annual rate of job growth for the 10 major economic sectors in the South and United States between 1969 and 1998. In all sectors except agriculture, southern growth outpaced the national averages. Manufacturing jobs declined in the United States while they were increasing in the South, and agricultural jobs increased faster in the United States than in the South. These changes reflect the continuing shift away from agriculture to manufacturing in the early years of this period. While manufacturing increased in the South, all other sectors except agriculture increased at a higher rate. The largest increases were in the financial, insurance, real estate (FIRE); retail; and service sectors, with the service sector increasing at over 4 percent per year. This reflects the more recent shift from manufacturing to the service sector in the southern economy, a trend that is expected to continue.

Between 1969 and 1998, wages increased faster than jobs for all States (fig. 10.3); the largest increases occurred in Florida, Texas, Georgia, and North Carolina. The smallest increases occurred in Alabama, Kentucky, Oklahoma, and Louisiana. Mississippi and Arkansas have the smallest State economies; Florida and Texas have the largest.

Poverty and unemployment—The nearly continuous growth in the southern economy has not benefited everyone equally. Some segments of the population still suffer from high unemployment rates, even while the overall rate is quite low. Similarly, there are groups and places with higher-than-average poverty rates in a region with poverty rates historically higher than the United States average.

Poverty rates in the South have declined by one-third over the past 30 years (U.S. Department of Commerce, Bureau of the Census 2000a, 2001). The gap between the South and the country as a whole has narrowed, but the South still experiences a slightly higher rate (fig. 10.4). Between 1969 and 1999, the sharpest declines in poverty rates occurred in Mississippi (19.3 percent), Arkansas (13.1 percent), and South Carolina (12.2 percent). Texas had the lowest reduction (3.8 percent).

Data on poverty broken down by State, race, and gender are available from the Current Population Survey (U.S. Department of Commerce, Bureau of the Census 2001) conducted jointly by the Bureau of the Census and the Bureau of Labor Statistics. Note, however, that because of survey design, reliable estimates of poverty by gender and race are available only for the Census South Region, which includes West Virginia. Poverty rates in the South differ substantially by sex and race (fig. 10.5). Females have higher rates of poverty than males, and both black and Hispanic rates are more than twice the rate for white

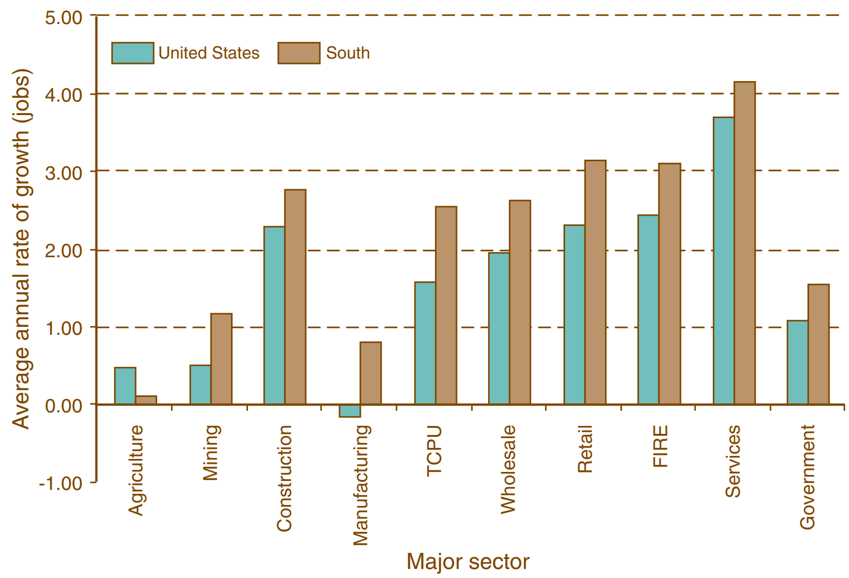

Figure 10.2—Average annual rate of growth in jobs in the South and United States, 1969 to 1998.

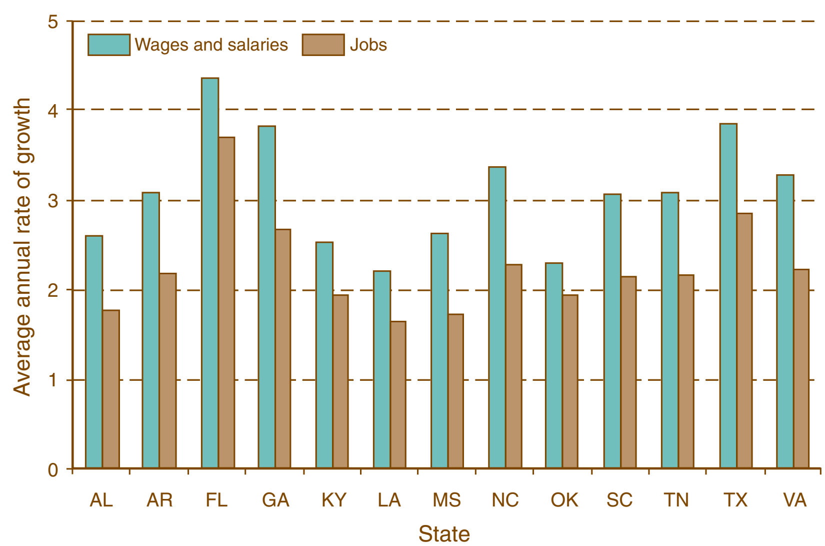

Figure 10.3—Average annual rate of growth in jobs and wages by Southern State, 1969 to 1998.

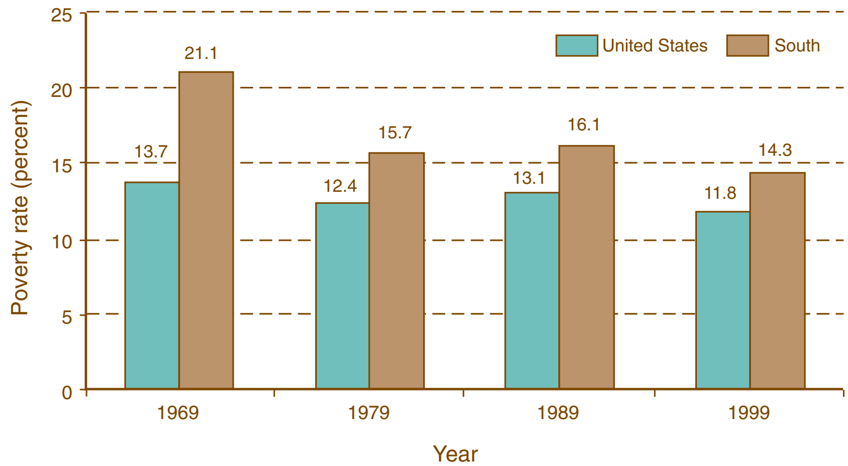

Figure 10.4—Poverty rates in the United States and in the South, 1969 to 1999.

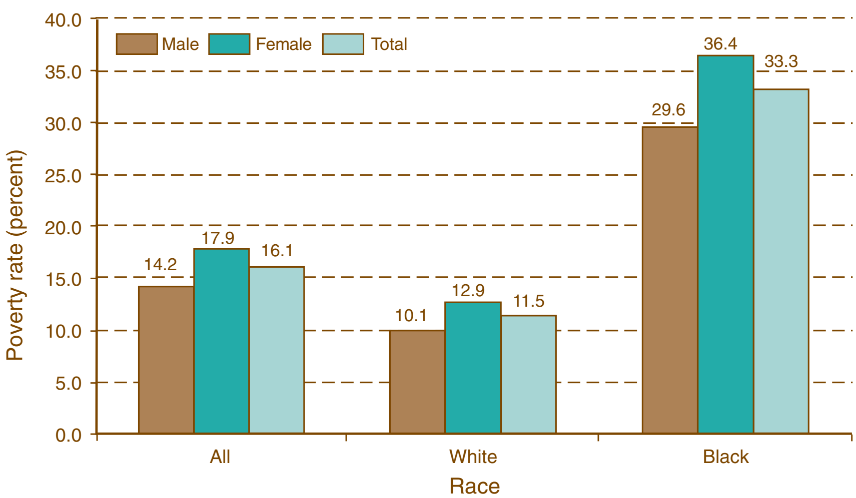

Figure 10.5—Poverty rates in the South by race and gender, 1995.

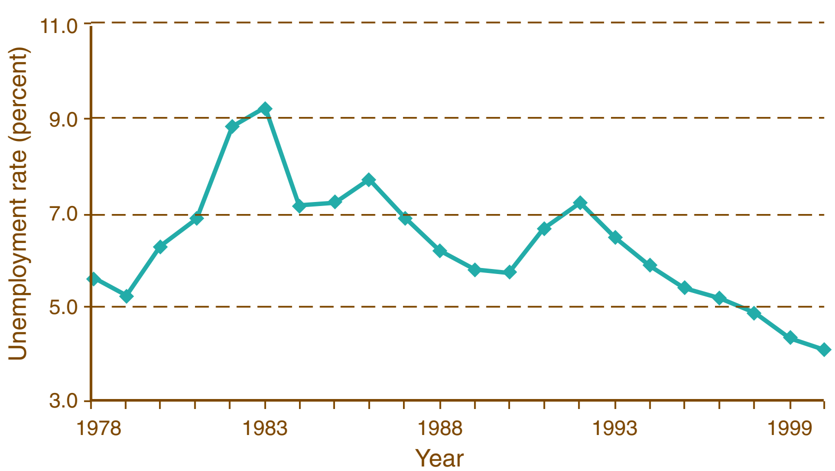

Figure 10.6—Unemployment rate in the South, 1978 to 1999.

southerners. As a group, black females have the highest poverty rates.

The average unemployment rate for the South during the period 1978 to 1999 was 6.2 percent. Like poverty rates, unemployment rates differ across races. The average unemployment rate among black southerners between 1981 and 1998 was 12.1 percent, while that for whites was 5.2 percent. The South's annual unemployment rate of 4.1 percent in 1999 represents a 1.5 percent decrease from 1978. Florida and Virginia led this decline with decreases of 2.8 percent and 2.6 percent, respectively, but improvement occurred throughout the South. Three Southern States had unemployment rates of 5 percent or lower in 1978, compared to 11 States in 1999.

The sharp spikes in the unemployment rate in the early eighties and early nineties (fig. 10.6) roughly correspond to declines in growth of U.S. Gross Domestic Product. Alabama's unemployment rate was 14.4 percent in 1982, while Tennessee's reached 11.8 percent. During the period from 1978 to 1999, unemployment for the South peaked at 9.2 percent in 1983.

Forest-Based Sectors of the Southern Economy

Measuring contributions to the local economy—Forest-based sectors of the economy include timber production, wood-processing industries, recreation and tourism deriving from forest land, and the contribution of the management of the national forests to the local economy. Jobs and income are the quantity and price measures, respectively, of a single input, labor, to the production or provision of a good or service. The production of lumber, for example, requires other inputs including timber, machinery and buildings, and energy. The provision of recreation requires inputs of labor, buildings, goods, and services. Because the outputs are assumed to be produced efficiently, labor may be substituted for, or may substitute for, other inputs in the production process. Thus, examining jobs and income alone will not provide a complete picture of the contribution of forest-based sectors to the regional economy.

In addition, lack of data and modeling ability prevent us from examining the nonmonetary transactions between industries and households. Thus we cannot isolate the impacts of one industry on another, or the impacts of industries on communities and individuals, except through transactions. These types of nonmonetary impacts are addressed qualitatively in chapter 12.

This analysis includes an evaluation of sector contributions to value added, total industry output, and GRP. Value added is the total income for a sector and includes wages and salaries, property income, and proprietor income. Wages and salaries are the largest component of income, and represent the total price of labor used in production. Southwide, wage and salary income comprise 58 percent of value added. Value added, less indirect business taxes, is referred to as gross industrial product, which when summed over a region represents GRP. GRP is at present the best overall measure of the size and state of the regional economy. GRP is comparable to gross domestic product at the national level. GRP is acknowledged, however, to have significant limitations when measuring effects on natural capital, such as forests, water, and air. Both data and modeling limitations must be overcome before a more adequate measure, often referred to as natural resource accounting, is available for use in this type of assessment.

Extensive data are available on manufacturing industries and on certain components of the service and retail trade sectors. These data allow us to formulate a picture of the contribution of forests to the economy over time. However, while the manufacturing data may pertain directly to timber production and processing, the recreation portion of the service and retail sectors is not clearly identified. In the time-series analysis below, we use hotels and lodging plus eating and drinking places to proxy for the tourism industry, referred to as tourism-related sectors. While this may be a suitable proxy for the size and concentration of the tourism sector, it is clearly different than the size and concentration of outdoor recreation or forest-based recreation. Much forest-based recreation involves camping, backpacking, hunting, or hiking, which may require neither local lodging nor restaurants. In addition, purchases of other goods and services, including transportation, are not included in these time-series data. Therefore, these should not be viewed as total contributions but as a proxy for the trend in the recreation sector. Further detail is developed in the following assessment of direct and total impacts of outdoor- or forest-based tourism for 1997.

We used input-output methods for the analysis of economic linkages and the total contribution of the forest-based sectors to the economy for 1997. These methods capture the indirect and induced effects of forest-based economic activities, as well as both the backward and forward linkages in the economy. Direct impacts are jobs, wages, and value added to a sector or lost from a sector in response to changes in final demand for that sector. Indirect impacts result when a producer buys inputs from other sectors within the region. Induced impacts are generated when an employee of a directly or indirectly impacted sector spends disposable income in the local economy. Backward linkages are impacts traced from any point in the production process back to the initial producer. For example, 2 by 4s purchased at a hardware store can be traced back to the tree farmer. Forward linkages, often referred to as downstream processing, represent subsequent processors of the commodity in question. For example, for timber, a forward linkage is the milling of logs into lumber.

Wood Products Sectors

Changes in wood products sectors over time—Between 1987 and 1997, the South's share of U.S. manufacturing jobs increased from 30.8 to 31.4 percent. At the same time, the South's share of wood products sector jobs increased from 36.5 to 39.3 percent (fig. 10.7). Southern jobs in both the lumber and wood products (SIC 24) and pulp and paper (SIC 26) sectors have increased faster than for all manufacturing, while the percentage of all furniture jobs in the South decreased between 1992 and 1997. This increase in the percentage of the industry located in the South is in contrast to the percentage of southern jobs in the wood products industry. More of U.S. production of wood products is occurring in the South, but wood products are a smaller percentage of southern jobs. The same is true of income and value added. The percentages of southern income and value added deriving from wood products have declined, while the percentages of U. S. wood products income and value added that are in the South have increased.

The 13 Southern States vary widely in the percentage of jobs that are in wood products sectors (fig. 10.8). Wood products sectors here include all of SIC 24, 25, and 26 (mobile homes were not excluded). For 1998,

Figure 10.7—Percent of U.S. manufacturing and wood products jobs in the South, 1987 to 1997.

proportions ranged from 0.5 percent in Oklahoma to more than 5 percent in Mississippi. Trends for all States were generally downward, though the lowest point was in 1982, coincident with a low point for wood products output in the United States. These peaks and valleys are consistent with trends for the general U.S. economy.

The trends in percentage of income from wood products sectors are very similar to the trends in percentage of jobs (fig. 10.9). They are generally downward, but with wide variation among States. Note, however, that the percentage of income from wood products was nearly double the percentage of jobs. For example, in 1998, 8 percent of Mississippi income derived from wood products, while only 5 percent of jobs derived from wood products. Note that the 1982 percentage drop is more dramatic for income than for jobs, most likely representing a decline in hours of work per job.

The percentages of all southern jobs and income coming from wood products are declining. This decline does not necessarily imply that the industry is shrinking. In fact, output from the industry is rising, but the amount of labor used (and thus wages paid) per unit of output is smaller. This substitution between inputs in the production of lumber has been examined specifically for sawmills (Abt and others 1994). This study found that increases in labor productivity (3 to 4 percent per year) were higher than for

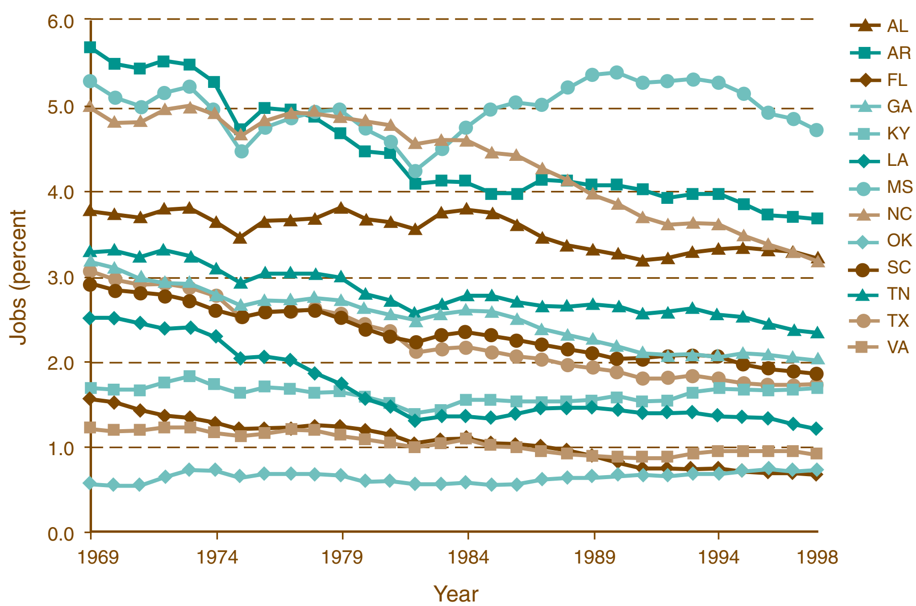

Figure 10.8—Percent of all jobs in wood products sectors in Southern States, 1969 to 1999.

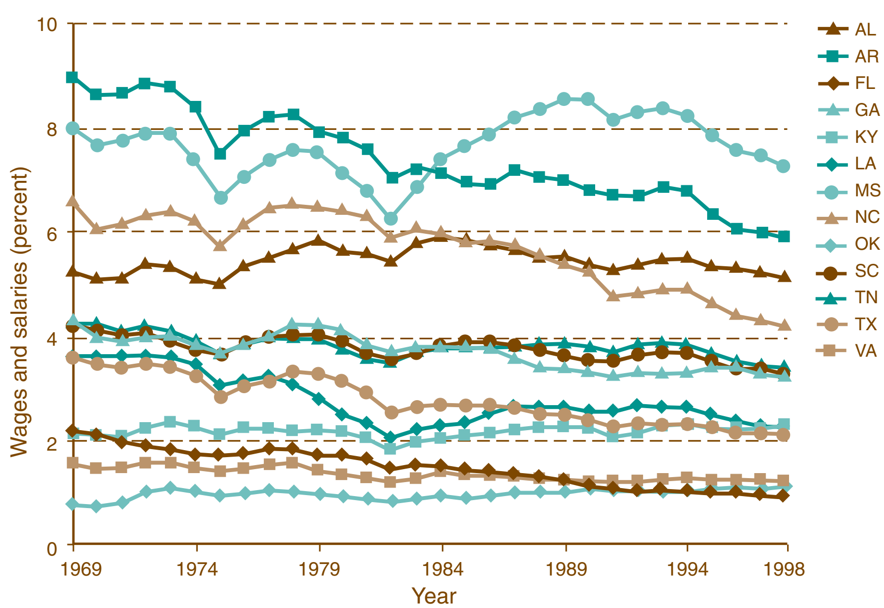

Figure 10.9—Percent of all wages in wood products sectors in Southern States, 1969 to 1998.

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Table 10.1—Direct employment, employee compensation, value added, gross regional product, and total industry output for wood products related sectors, 1997

IMPLAN sector				Direct impacts by IMPLAN wood products sector				
Number	Name	Aggregate sector name	All wood products	Employment	Employee compensation	Value added	Total industry output	Gross regional product
			Percent	*Jobs*	- - - - - - - - - *Dollars (millions)*	- - - - - - - - - -		
22	Forest products	Timber	1.2	25,991	38	1,151	1,460	1,116
24	Forestry products	Timber	3.1	13,485	147	1,618	3,678	1,240
133	Logging camps and logging contractors	Logging	6.4	47,331	1,133	2,824	7,583	2,780
134	Sawmills and planning mills, general	Sawmills	9.5	71,531	1,993	3,202	11,232	3,138
135	Hardwood dimension and flooring mills	Sawmills	1.5	25,931	591	862	1,739	852
136	Special Product Sawmills, N.E.C.	Sawmills	0	509	15	22	37	22
137	Millwork	Sawmills	2.2	29,582	776	1,003	2,569	988
138	Wood kitchen cabinets	Sawmills	1.3	21,858	518	755	1,521	746
139	Veneer and plywood	Sawmills	4.2	36,149	1,305	1,903	4,967	1,872
140	Structural Wood Members, N.E.C.	Sawmills	1.4	15,246	411	584	1,663	574
141	Wood containers	Sawmills	.3	5,146	103	147	355	145
142	Wood pallets and skids	Sawmills	.9	16,714	341	475	1,071	469
144	Prefabricated wood buildings	Sawmills	.4	4,948	126	176	524	173
145	Wood preserving	Sawmills	1.8	7,846	221	431	2,146	420
146	Reconstituted wood products	Sawmills	2.0	10,981	390	876	2,405	862
147	Wood Products, N.E.C.	Sawmills	1.1	17,492	416	634	1,340	626
148	Wood household furniture	Wood furniture	5.2	73,696	1,830	2,370	6,123	2,335
149	Upholstered household furniture	Wood furniture	5.1	65,463	1,769	2,143	6,085	2,107
150	Metal household furniture	Wood furniture	.9	9,908	262	341	1,029	336
151	Mattresses and bedsprings	Wood furniture	1.1	11,057	347	459	1,263	454
152	Wood tv and radio cabinets	Wood furniture	.2	1,822	49	58	184	56
153	Household Furniture, N.E.C.	Wood furniture	.2	3,853	98	111	254	110
154	Wood office furniture	Wood furniture	.5	7,932	241	279	611	275
155	Metal office furniture	Wood furniture	1.1	6,143	198	276	1,266	270
156	Public building furniture	Wood furniture	1.8	12,444	395	583	2,134	571
157	Wood partitions and fixtures	Wood furniture	.6	9,466	272	327	682	324
158	Metal partitions and fixtures	Wood furniture	.9	8,674	285	375	1,039	369

continued

Table 10.1—Direct employment, employee compensation, value added, gross regional product, and total industry output for wood products related sectors, 1997 (continued)

IMPLAN sector			Direct impacts by IMPLAN wood products sector					
Number	Name	Aggregate sector name	All wood products	Employment	Employee compensation	Value added	[1]Total industry output	Gross regional product
			Percent	*Jobs*	- - - - - - - - *Dollars (millions)* - - - - - - - -			
159	Blinds, shades, and drapery hardware	Wood furniture	.4	4,401	114	182	444	180
160	Furniture and Fixtures, N.E.C.	Wood furniture	.7	4,205	124	206	823	203
161	Pulp mills	Pulp and paper	3.3	8,315	546	1,205	3,852	1,160
162	Paper mills, except building paper	Pulp and paper	11.0	53,130	3,371	5,064	13,040	4,922
163	Paperboard mills	Pulp and paper	9.9	29,712	1,910	3,306	11,767	3,188
164	Paperboard containers and boxes	Pulp and paper	9.2	60,867	2,567	3,188	10,880	3,072
165	Paper coated and laminated packaging	Pulp and paper	1.0	5,428	265	404	1,159	392
166	Paper Coated & Laminated N.E.C.	Pulp and paper	.9	5,485	272	426	1,089	414
168	Bags, paper	Pulp and paper	1.3	8,733	298	469	1,482	453
169	Die-cut paper and board	Pulp and paper	.3	2,939	92	125	361	120
170	Sanitary paper products	Pulp and paper	4.9	10,382	536	1,859	5,828	1,800
171	Envelopes	Pulp and paper	.4	3,722	139	168	500	163
172	Stationery products	Pulp and paper	.3	1,581	62	116	340	112
173	Converted Paper Products, N.E.C.	Pulp and paper	1.6	11,295	427	655	1,914	635
Total all wood products			100.0	771,392	25,439	42,022	120,543	40,688

Source: Minnesota IMPLAN Group, Inc. 1997.

other inputs, which may result from increased use of capital in production. Thus, less labor could be used to produce the same amount of lumber. In Georgia, for example, while wood products wages represented 15.7 percent of the value of wood products shipments in 1982, wages were only 13.2 percent of the value of shipments in 1997.

Impact analysis for 1997—In 1997 the wood products sectors contributed over 770,000 direct jobs to the southern economy, $120 billion in total industry output, and over $40 billion in GRP (table 10.1). Table 10.1 also shows the aggregated sector subset we used to simplify the discussion below. The direct impacts are shown for private timber production, logging, sawmills, wood furniture, and pulp and paper. This table also includes the proportion of wood processing accounted for by each individual sector, as well as the direct employment, income, value added, total industry output, and GRP for each individual sector.

To calculate the indirect (what producers buy) and induced (what consumers buy) effects of the wood products industry, we used the IMPLAN input-output model to develop response coefficients, such as the number of jobs per million dollars of final demand. Response coefficients were also developed for public timber harvests by using the expenditures made by the national forests in the South to proxy for the production relationships of public timber producers. Public timber production coefficients were determined from the National Forest System (NFS) accounting as reported for each forest at the USDA National Finance Center. Expenditures by the national forests were classified into a program area, and all of the timber classifications were bridged to IMPLAN sectors. This procedure results in expenditures in each sector for the production of national forest timber.

The response coefficients show the total impacts on the economy from each $1 million increase in final demand for that industry's output. Special care was taken to eliminate double counting by eliminating local purchases between modeled sectors. A different set of response coefficients would be needed to measure the effect of, for example, adding a mill to a local

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Table 10.2—Direct effects of aggregate wood products sectors compared to agriculture sectors, 1997

Sector	Employment	Employee compensation	Value added	Total industry output	Gross regional product
	Jobs	*Dollars (millions)*			
Timber	39,475	185	2,769	5,138	2,355
Logging	47,331	1,133	2,824	7,583	2,780
Sawmills	263,933	7,207	11,070	31,569	10,886
Wood furniture	219,064	5,860	7,503	21,114	7,387
Pulp and paper	201,589	10,610	17,191	53,035	16,635
All wood products	771,392	24,995	41,357	118,438	40,043
Total, South	39,988,010	1,094,474	1,885,326	3,353,628	1,735,953
	Percent				
Southern economy in					
Timber production	0.22	0.12	0.30	0.38	0.30
Wood processing	1.71	2.16	1.90	3.15	2.01
Farming	3.00	.60	1.50	1.70	1.60
Food processing	1.27	1.61	2.22	4.19	1.94

Source: Minnesota IMPLAN Group, Inc. 1997.

Table 10.3—Total impacts for 1997 wood products output levels

	Total impact values (direct+indirect+induced) for 1997 output levels				
Sector	Employment	Employee compensation	Value added	Total industry output	Gross regional product
	Jobs	*Dollars (millions)*			
Public timber	8,854	223	422	777	422
Timber	110,527	1,679	4,905	10,081	4,181
Logging	99,750	2,462	5,246	11,967	4,982
Sawmills	688,768	18,614	32,035	70,909	29,924
Wood furniture	530,916	14,509	23,096	50,557	21,545
Pulp and paper	771,430	26,355	47,041	107,283	43,584
Total	2,210,246	63,842	112,745	251,574	104,639
Southern production (%)	5.53	5.83	5.98	7.50	6.03

Source: Minnesota IMPLAN Group, Inc. 1997.

economy and counting all backward linkages from the mill to logging to timber production.

Table 10.2 shows the direct impacts of the five aggregated wood products sectors (not including the public timber sector, whose jobs and income are included in the government sectors of the input-output database). Also included in this table is the percentage of the southern economy in timber production and wood processing as well as the percentage in agriculture, including both farming and food processing. Thus, timber production and subsequent wood processing (most of SIC 24, 25, and 26) directly constitute about 2 percent of the southern economy. More of total industry output (3.53 percent) than jobs (1.93 percent) derives from wood processing, implying that returns to capital are higher than average. Farming, the counterpart to timber

Table 10.4—Selected counties with high wood products concentration and high national forest land ownership

County name	State	National forest harvest receipts	Total forest harvest receipts	Harvest receipts from national forests	Land in national forests	Wood products jobs	Wood products jobs	Wood products jobs 1996	Jobs in wood products 1996	Per capita income	Removals per acre	Removals per private acre	Forest in planted pine
		Dollars (millions)		- - - - Percent - - - -		No.	Percent	No.	Percent		Cubic feet per acre		Percent
Montgomery	AR	4.72	5.84	0.81	0.67	129	0.04	225	0.07	8,343	0.025	0.105	0.131
Newton	AR	.1	1.162	.09	.37	157	.07	104	.04	7,114	.017	.038	.000
Polk	AR	.76	2.328	.33	.37	560	.06	559	.06	8,884	.029	.059	.127
Scott	AR	6.99	7.091	.99	.64	346	.07	472	.09	8,360	.034	.150	.099
Liberty	FL	.42	1.131	.37	.51	323	.16	279	.13	11,500	.024	.053	.321
Grant	LA	4.47	4.897	.91	.35	497	.10	472	.10	8,330	.077	.134	.147
Franklin	MS	3.11	3.785	.82	.26	464	.16	444	.17	7,426	.117	.165	.052
Perry	MS	3.08	24.953	.12	.39	928	.28	1,025	.27	7,418	.043	.078	.246
Cherokee	NC	.1	2.06	.05	.32	408	.04	500	.04	9,258	.020	.032	.024
Graham	NC	.17	1.622	.10	.61	793	.24	752	.21	8,877	.010	.033	.000
Transylvania	NC	.09	1.861	.05	.36	1,389	.11	1,729	.13	12,737	.010	.017	.000
Monroe	TN	.37	2.764	.13	.36	1,012	.07	1,458	.10	9,080	.027	.059	.000
Sabine	TX	2.27	6.649	.34	.30	719	.22	747	.20	10,539	.100	.156	.187
Smyth	VA	.11	2.295	.05	.26	2,466	.14	2,527	.11	9,613	.026	.046	.000
14-county average						728	.13	807	.12	9,106	.040057	.080484	0
Southwide average						615	.04	616	.04	10,494	.05	0	.1613

production, is 3 percent of employment but only 1.7 percent of total industrial output. The contributions of farming are greater than those of the other major rural land use, timber, which constituted only 0.22 percent of jobs and 0.38 percent of total industrial output. The wood-processing sectors are similar to the food-processing sectors (SICs 20 and 21), which constitute a slightly larger percentage of the southern economy.

In 1997, public timber harvests had a value of $478 million, $96 million of which was from national forests, while private harvests had a value of $5,138 million. These numbers do not include harvests from Federal lands other than national forests. Tracking the forward-linkage (downstream processing) effects of both public and private harvests through the economy resulted in 2.2 million jobs and $104.6 billion of GRP (table 10.3), amounting to approximately 5.5 percent of jobs and 6.0 percent of GRP in the South. Public timber harvests constituted 8.5 percent of the value of all timber harvests, with only 1.7 percent from national forests.

Although the national forests contribute only a small amount to the total harvest value in the South, in some communities and counties the national forests play a large role in the wood-processing sector and in the local economy. The national forests spend more than $76 million on the timber program in the South, approximately one-third of the southern regional budget for 1996. This program is small, however, relative to the private harvests in the region. Table 10.4 shows 14 southern counties where the national forests manage more than 25 percent of the forest land and where the proportion of employment in wood products sectors is greater than 4 percent, approximately twice the Southwide average. Also included in this table are the county level per capita income, removal rate on all land, and removal rate on private land.

Future impacts of the wood-processing sectors on the southern economy are expected to continue at about the same level. The total wood products workforce has stayed fairly constant over the last 30 years, indicating that increases in production have been offset by increases in labor productivity. Using the increased harvest numbers from chapter 13 in the

IMPLAN input-output model requires an assumption that technology does not change, which is unrealistic over the 40-year projection period. Thus, we conclude that wood products will continue to be important contributors to the economy, and that labor use might not change. Given the projected shifts in harvest location from chapter 13, we would expect jobs to shift to areas of increasing harvest intensity and away from areas of decreasing harvest intensity. The degree of this shift will depend on the relative costs of industrial relocation versus raw materials transportation.

Recreation/Tourism Sectors

As in our analysis of wood products, we first examined the direct tourism-related jobs over time and by State. We then estimated the direct, indirect, and induced effects of forest-based recreation in 1997. The analysis of the role of forests in recreation- and tourism-based employment and income is hampered by the lack of information on exactly how much of the local economy derives from recreation and tourism (Kass and Okuba 2000). Unlike the wood products sectors, where data are collected in categories that relate closely to forests and forestry, expenditures by visitors to forests are lumped together with expenditures by residents and other travelers for such items as eating and lodging.

As noted earlier in the State-level analysis, we used lodging and eating places to proxy for tourism-related industries. For 1996, we developed a measure of outdoor recreation-based tourism at the county level and compared this to the totals from the lodging and eating places. The correlation was quite high (greater than 0.98) and significant, and the rankings were similar. Thus, we concluded that the time-series of overall tourism was an adequate proxy for the actual but unobtainable time-series of outdoor recreation-based tourism.

In contrast, the indirect effects were more precisely modeled using three different techniques (a complete discussion of these methods follows). Thus, the discussion of the time-series direct jobs and income in tourism-related sectors is not directly comparable to the estimates of direct, indirect, and induced effects of forest-based and outdoor recreation-based tourism.

Few forest-based recreation activities generate direct income for landowners although the Fee Demonstration Program for the national forests and hunting leases on private land do bring some income. The major economic impact is the money spent in local communities by recreationists. This includes the costs of transportation, purchases of equipment and supplies, and purchases of lodging and restaurant services. As a result, the recreation analysis is very different from the timber analysis. Rather than tracking a physical commodity through several processing steps, we trace the impact of a nonmaterial forest output—the opportunity to recreate—to the final consumer. There are no forward linkages, in the market sense, from the forest to the final consumer. There are only backward linkages from the recreation consumer to the producers of the supplies the consumer buys.

Recreation output from the forest is nonmaterial; it is the setting that is provided. As this output is not being processed in any way, we have no sales value for secondary processing industries as we did for timber. Therefore, to measure the economic impact of recreation activities, we estimated what recreationists purchased in local economies.

Changes in recreation/tourism sectors over time—The percentages of all southern jobs that are in the hotel and lodging and the eating and drinking place sectors have increased in all 13 Southern States (fig. 10.10). Percentages for Mississippi and Louisiana reflect significant increases in the early 1990s, likely due to changes in State gambling laws. Similar increases occurred in wages and salaries (fig. 10.11) between 1969 and 1998. Florida had the largest concentration of tourism-related jobs and income, exceeding 7 percent in 1998. There is much less variation by State in tourism-related jobs and income than in wood products jobs and income. Tourism-related jobs are 5 to 6 percent of all jobs, and 3 to 6 percent of income is in tourism-related sectors. Unlike in the wood products sector, these sectors represent a larger share of jobs than of income. Because actual wage rates are not available, and the jobs in this dataset do not represent full-time equivalents (40-hour weeks), the lower income per job may reflect part-time jobs, and in any case reflects only the average, not individual wage rates.

Impact analysis for 1997—We used three different methods to estimate total outdoor or forest-based recreation impacts in the South. These methods give us a range of impacts, with a low of 317 million forest visitor days and a high of 1,268 million visitor days. The first method is based on the

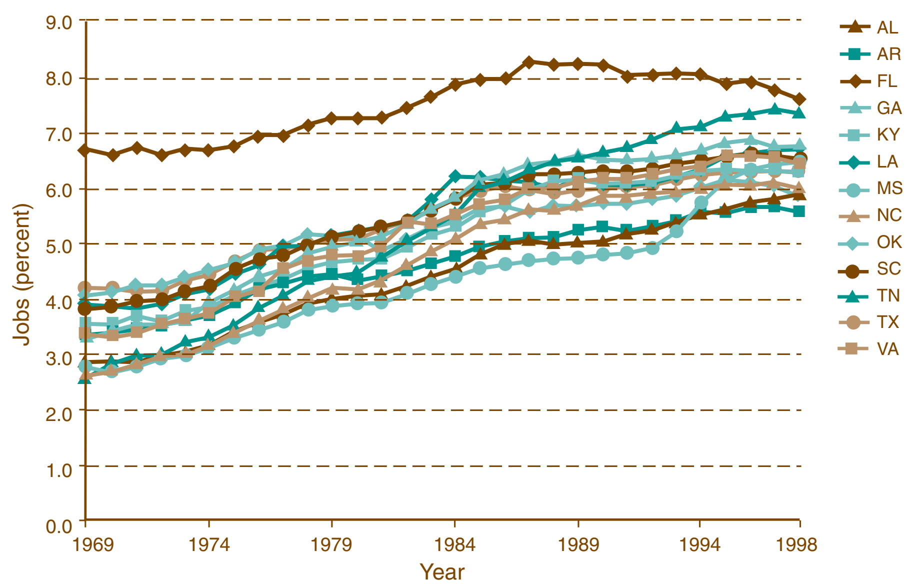

Figure 10.10—Percent of all jobs in recreation/tourism sectors in Southern States, 1969 to 1999.

most recent NFS estimates of visits to Region 8 in 2000 (U.S. Department of Agriculture, Forest Service 2001). This method includes expenditures made for durables, nondurables, and services within 50 miles of the recreation site. We allocated NFS recreation visits using two different methods: (1) participation from NSRE (NFS-P) and (2) land area in national forests (NFS-L). The second method uses the national TTSA (Kass and Okuba 2000) to attribute output to travel and tourism, then estimates forest-based proportions using recent study results that outdoor recreation comprises 19 percent of all leisure tourism visits and 33 percent of all leisure tourism expenditures (Pennsylvania Department of Conservation and Natural Resources 1999). This method does not include durables expenditures, but includes all other expenditures for outdoor recreation-related tourism. The third method also uses the 19 and 33 percentages, but applies them to State-level estimates of total travel and tourism outputs from the Travel Industry Association of America (1999). Similar to the TTSA method, this method does not include durables purchases, accounts for all other purchases regardless of where made, and includes expenditures from all outdoor recreation, not just forest-based outdoor recreation.

NFS-methods—National forest visits in the Southern Region were estimated at 24,869,000 for 2000 (Personal communication. 2001. Don English, Research Social Scientist, Forestry Sciences Laboratory, Southern Research Station, 320 Green Street, Athens, GA 30602-2044). The NFS-P method assumed that the proportion of visits to public land was equal to the proportion of activity days occurring on public land in the NSRE (56 percent). Further, the percent of visits to national forest land was equal to the proportion of public land managed by the national forests (30 percent). This approach resulted in an estimated 17 percent of the recreation visits occurring on NFS land, and thus the remaining 83 percent occurred on private and other public lands (148,115,474 visits) (table 10.5). For the NFS-L method we assumed that all forests were visited in proportion to their acreage in the South, so we divided the NFS visits by the percent of all forest land in national forests (6 percent), resulting in 410,043,596 total forest visits.

Visits are multi-day trips, so we adjusted the visit estimates using trip lengths from the CUSTOMER survey (available from Ken Cordell, Project Leader, Forestry Sciences Laboratory, Southern Research Station, 320 Green Street, Athens, GA 30602-2044) and activity allocation from NSRE to get total days of forest visits. To get days, we used a weighted average length of trip for nonresidents and assumed a single-day visit for residents. The weights were based on the proportion of total trips that were a single type, such as camping, using the NSRE data on participation. The average of 2.14 days per trip resulted in an estimate of the total number of forest-based recreation days of 317,123,332 for the NFS-P method and 878,448,994 for the NFS-L method.

These activity estimates were multiplied by the response coefficients for direct and total impacts derived from IMPLAN. We used expenditure profiles detailing what people spent on various activities from two previously developed surveys, the Public Area Recreation Visitor Survey (PARVS) (available from Ken Cordell, Project Leader, Forestry Sciences Laboratory, Southern Research Station, 320 Green Street, Athens, GA 30602-2044) for recreation, and the U.S. Fish and Wildlife Service (FWS) surveys for hunting and fishing, both in dollars of expenditures per person per day (U.S. Fish and Wildlife Service 1999). The response coefficients for the recreational activities (developed camping, mechanized travel, other recreation, trail use, and winter activities) were developed using PARVS expenditures bridged to IMPLAN sectors. Hunting and fishing response coefficients were developed by bridging FWS survey data to IMPLAN sectors. These profiles include expenditures within 50 miles for PARVS and within the State for FWS, for both residents and nonresidents. Separate coefficients were estimated for residents and nonresidents. Impacts for residents are substantially lower than for nonresidents.

For both scenarios, allocations to individual forest-related activities were based on the percentages from NSRE. Table 10.6 shows the number of forest visitor days for both NFS-L and NFS-P. Mechanical travel (resident and nonresident), other (resident), trail use (resident and nonresident), freshwater fishing (nonresident), and other (non-resident), are the largest in number of visitor days.

The direct and total impacts by activity are shown in table 10.7 for NFS-P and table 10.8 for NFS-L. Direct jobs range from 136,944 to 379,116 and total jobs (direct plus indirect plus induced) range from 254,591 to 704,812 jobs. Direct

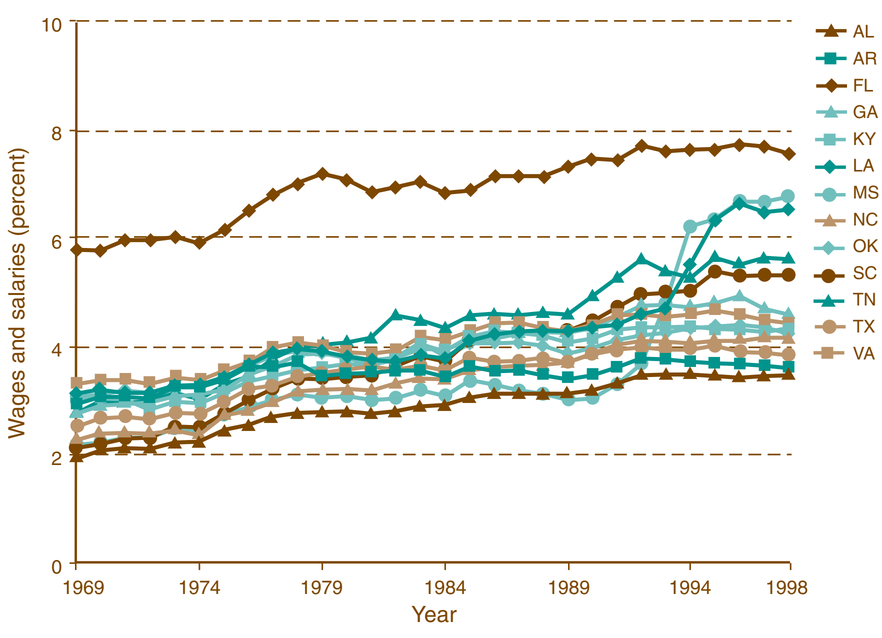

Figure 10.11—Percent of all wages and salaries in recreation/tourism sectors in Southern States, 1969 to 1998.

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Table 10.5—Development of NFS land and NFS participation recreation impacts analysis, 1997

Visits to national forests in the Southern Region (NVUM)	24,869,000
Weighted average trip length (CUSTOMER)	2.14
NFS land	
Forest land (FIA) (acres)	214,850
National forest (CRS) (acres)	13,031
Forest land in national forest (percent)	6
Visits to all forests in the Southern Region	410,043,596
Total forest visitor days	878,448,994
NFS participation	
Total forest-based recreation participation days (NSRE)	5,044,205,000
Forest-based recreation participation days on public lands (56 percent of participation on all lands)	2,823,120,150
Participation on national forest lands (percent) (approx. 30 percent of all public lands are national forests)	17
Visits to all forests in the Southern Region (28 percent of total forest visits)	1,481,155
Total forest visitor days (2.14 days per trip)	317,312,332

contribution to GRP ranges from $3,805 to $10,533 million, while total GRP from recreation ranges from $9,350 to $25,886 million for this method.

TTSA methods—The second method relies on the TTSA for most data (Kass and Okuba 2000) supplemented with IMPLAN data. IMPLAN response coefficients for each of the affected sectors were used. The TTSA uses national-level data on consumer expenditures and the national input-output tables to attribute demand to tourism. Only travel farther than 50 miles from home is represented, so the data were adjusted using the percentages of resident and nonresident travel from the NSRE. The TTSAs estimate foreign and domestic nonresident leisure tourism, as well as business tourism. Table 10.9 lists the sectors that are assumed to be influenced by tourism. We used the percentage of each sector that was attributed to leisure tourism and applied that percentage to total southern output (from IMPLAN) from those sectors to estimate southern leisure tourism. Leisure tourism is determined from the proportion of industry output that is purchased by tourists more than 50 miles from home.

We then used two different levels to represent the proportion of outdoor recreation expenditures, 19 and 33 percent. These percentages were derived from a study of outdoor recreation tourism in Pennsylvania (Pennsylvania Department of Conservation and Natural Resources 1999). If the primary purpose of the vacation was outdoor recreation and involved overnight travel or travel farther than 50 miles from home, then the vacation was considered an outdoor recreation vacation. The study estimated that 59 percent of all travel included some form of outdoor recreation, but that only 19 percent had outdoor recreation as the primary purpose. The study also found that outdoor recreation travel is increasing faster than other forms of travel, and that outdoor recreation travelers spend more per person per trip than the average leisure traveler. While this study was conducted for a different ecoregion and a single State, other similar research was not found. We therefore used two of the numbers from this study: 19 percent of all travelers are outdoor recreation travelers, and 33 percent of all expenditures are made by outdoor recreation travelers. Those numbers represent the high and low bounds of the TTSA and TIA methods.

Tables 10.10 and 10.11 show the direct and total effects by sector assuming either the 19 or 33 percent in outdoor recreation. Direct employ-ment ranges from 212,193 jobs to 427,317 jobs, and direct GRP ranges from $6,145 to $11,555 million. Total employment (direct plus indirect plus induced) ranges from 379,373 to 748,094 and total GRP from $13,492 to $25,624 million dollars. The largest impacts are from the airline, eating and drinking, hotel and lodging, and recreation and entertainment sectors.

TIA method—The third method used the TIA report for 1997 in combination with inputs from the Pennsylvania Department of Conservation and Natural Resources (DCNR) and the TTSAs for 1997. The TIA developed impacts for travel by State for 1997 (Travel Industry Association of America 1999) using an input-output model. The results include total impacts for expen-ditures, payroll, and employment. TIA travel includes only travel farther than 50 miles from home, so the data were adjusted using the percentages of resident and nonresident rec-reators from the NSRE. We applied the percentage of tourism that is leisure tourism (from the TTSA) and the percentage attributable to outdoor recreation (19 and 33 percent, from the Pennsylvania DCNR study). These percentages were also adjusted by the proportion of the State in forest to account for the differences in largely unforested States such as Texas and Oklahoma. These latter two States had the lowest percent of tourism in outdoor recreation-related tourism (table 10.12), while Alabama, Georgia, and Mississippi had the highest rates. Table 10.12 also has the TIA data for all tourism direct expenditures, payroll, and employment.

Table 10.13 shows the direct and total effects from applying both the 19 and 33 percent of tourism as outdoor recreation related. Direct effects jobs range from 276,000 to 480,000 and expenditures from $16 to $28 billion. Total jobs range from 579,000 to 1,006,000, and total expenditures range from $38.5 to $66.9 billion. Total values were derived by using the multipliers developed at the national level for the TIA report.

Summary—table 10.14 compares the six estimates and also estimates the number of visitor days associated with the TTSA and TIA methods. The relationship between jobs and visitor

Table 10.6—Allocation of tourism from NFS methods to activities, 1997

Activity	Tourism allocation to activities: Participation (NSRE)	Proportion on public lands (NSRE)	Proportion by activity (NSRE)	Forest visitors: By participation on public lands and activity length	By public land area and activity length
	Days (millions)			*Days (millions)*	
Resident					
Developed camping	35.67	0.68	0.01	2.24	6.21
Mechanized travel	664.70	.56	.13	41.81	115.76
Other	549.65	.66	.11	34.58	95.72
Trail use	448.60	.54	.09	28.22	78.12
Winter activities	13.68	.06	.00	.86	2.38
Big game hunting	64.50	.27	.01	4.06	11.23
Small game hunting	43.94	.33	.01	2.76	7.65
Other game hunting	4.65	.26	0	.29	.81
Fresh water fishing	146.00	.30	.03	9.18	25.43
Nonconsumptive wildlife	348.79	.72	.07	21.94	60.74
Nonresident					
Developed camping	96.43	.68	.02	6.07	16.79
Mechanized travel	1,084.50	.56	.21	68.22	188.87
Other	283.15	.66	.06	17.81	49.31
Trail use	431.00	.54	.09	27.11	75.06
Winter activities	54.72	.06	.01	3.44	9.53
Big game hunting	43.00	.27	.01	2.70	7.49
Small game hunting	39.72	.33	.01	2.50	6.92
Other game hunting	10.20	.26	0	.64	1.78
Fresh water fishing	288.00	.30	.06	18.12	50.16
Nonconsumptive wildlife	393.31	.72	.08	24.74	68.50
Total	5,044.21			317.31	878.45

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days in the NFS methods was used to calculate the visitor days associated with the TTSA and TIA methods. Estimated visitor days, and the other economic measures of jobs, income, etc., are ordered similarly, with the NFS-P method generating the lowest economic contributions, followed by the TTSA-19 and TIA-19 methods, and NFS-L, TTSA-33, and TIA-33 generating the highest contributions. Direct effects are 0.2 to 1.2 percent of total southern employment and 0.13 to 0.61 percent of total southern GRP. Total effects range from 0.38 to 2.62 percent of employment and 0.32 to 1.35 percent of GRP.

The USDA Forest Service recently released revised estimates of national forest visits based on a survey (U.S. Department of Agriculture, Forest Service 2001). These estimates will be prepared each year for all national forests. Estimates for the Southern Region, which were used in the NFS methods above, were 24.9 million visits in 2000. Table 10.15 shows the estimated visits and land area for each of the regions and for the United States as well as the visits per acre. This rate of visitation is highest in the Eastern Region, followed by the Southern Region at 1.89 visits per acre. These numbers are an indication of relative resource scarcity of national forest land for recreation. At this time, the bulk of the national forest land is located distant from most of the population, thus limiting its usefulness in alleviating this scarcity.

Participation in recreational activities has been projected to increase in the South (see chapter 11). It is likely that this recreation will be concentrated on Federal and State parks, forests, and coastlines. As such, these increases in participation will likely lead to increased jobs in areas with public recreation lands. Increases in labor productivity will occur in the leisure service sectors, but they are likely to be small relative to total output. Thus, labor will continue to be a major input into production of these services.

One aspect of recreational services that could change in the South is a potential increase in manufacturers of recreation products, leading to an increase in retention of backward linkages within the region, involving both returns to capital and to labor. We expect the proportion of the southern economy in outdoor recreation enterprises to continue to increase, comparable to increases in the national economy.

Relationship between recreation and wood products sectors in the economy—Discussions of the forest-based economy often center around the relationship between the wood products and the recreation and tourism sectors because both depend on the existence of forests (Morton 1994, Schallau 1994). While the relationship between the two uses may be obvious at an individual site, the landscape-level effects of these activities on the economy are not clear. The substitution of one site for another in both recreation and wood products

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Table 10.7—Direct and total impacts by activity from NFS-P recreation impacts analysis, 1997

Activity	1997 activity level	Jobs	Employee compensation	Value added	Total industry output	Gross regional product
	Days (millions)	*No.*	*- - - - - - - - Dollars (millions)*			*- - - - - - - -*
			Direct impacts for 1997 output levels			
Resident						
Developed camping	2	367	7	12	24	10
Mechanized travel	42	11,666	216	402	816	334
Other	35	8,263	156	293	586	244
Trail use	28	3,594	64	122	238	99
Winter activities	1	419	6	10	20	9
Big game hunting	4	420	10	19	41	16
Small game hunting	3	198	5	9	19	8
Other game hunting	0	34	1	2	3	1
Fresh water fishing	9	921	21	41	83	34
Nonconsumptive wildlife	22	1,638	37	75	159	63
Nonresident						
Developed camping	6	2,616	48	86	175	73
Mechanized travel	68	64,374	1,110	1,940	3,875	1,670
Other	18	10,910	196	351	704	299
Trail use	27	19,415	350	609	1,203	522
Winter activities	3	2,817	44	75	141	66
Big game hunting	3	642	15	29	63	25
Small game hunting	2	408	9	19	40	16
Other game hunting	1	170	4	8	16	7
Fresh water fishing	18	3,396	78	149	307	126
Nonconsumptive wildlife	25	4,675	108	216	461	183
Total	317	136,944	2,485	4,467	8,973	3,805
			Total impacts (direct+indirect+induced) for 1997 output levels			
Resident						
Developed camping	2	697	15	28	53	25
Mechanized travel	42	22,283	488	961	1,821	842
Other	35	15,946	353	693	1,305	607
Trail use	28	6,652	142	280	524	242
Winter activities	1	698	13	24	45	21
Big game hunting	4	908	23	46	90	40
Small game hunting	3	428	11	22	43	19
Other game hunting	0	73	2	4	7	3
Fresh water fishing	9	1,833	46	92	178	81
Nonconsumptive wildlife	22	3,472	86	175	348	154
Nonresident						
Developed camping	6	4,946	108	207	392	183
Mechanized travel	68	116,623	2,439	4,621	8,629	4,103
Other	18	20,313	436	837	1,571	740
Trail use	27	35,544	763	1,436	2,677	1,273
Winter activities	3	4,804	93	170	307	153
Big game hunting	3	1,360	34	69	137	61
Small game hunting	2	865	21	44	86	38
Other game hunting	1	360	9	18	36	16
Fresh water fishing	18	6,887	171	342	665	300
Nonconsumptive wildlife	25	9,902	248	507	1,005	447
Total	317	254,591	5,501	10,577	19,919	9,350

Table 10.8—Direct and total impacts by activity from NFS-L recreation impacts analysis, 1997

Activity	1997 activity level	Jobs	Employee compensation	Value added	Total industry output	Gross regional product
	Days (millions)	*No.*	*- - - - - - - - Dollars (millions)*	*- - - - - - - -*		
			Direct impacts for 1997 output levels			
Resident						
Developed camping	6	1,017	18	33	65	28
Mechanized travel	116	32,296	597	1,114	2,260	925
Other	96	22,877	433	812	1,622	675
Trail use	78	9,951	177	338	659	273
Winter activities	2	1,161	17	28	56	24
Big game hunting	11	1,163	26	53	112	44
Small game hunting	8	548	13	25	54	21
Other game hunting	1	95	2	4	9	4
Fresh water fishing	25	2,551	59	113	228	95
Nonconsumptive wildlife	61	4,533	104	207	441	175
Nonresident						
Developed camping	17	7,243	134	239	484	203
Mechanized travel	189	178,213	3,072	5,372	10,727	4,623
Other	49	30,202	543	972	1,949	829
Trail use	75	53,747	970	1,685	3,330	1,446
Winter activities	10	7,797	122	207	389	183
Big game hunting	7	1,777	41	81	174	69
Small game hunting	7	1,129	26	51	110	43
Other game hunting	2	470	11	21	46	18
Fresh water fishing	50	9,403	215	414	851	348
Nonconsumptive wildlife	68	12,943	299	597	1,275	506
Total	878	379,116	6,879	12,366	24,840	10,533
			Total impacts (direct+indirect+induced) for 1997 output levels			
Resident						
Developed camping	4	1,929	41	78	147	69
Mechanized travel	75	61,688	1,352	2,661	5,042	2,330
Other	62	44,144	978	1,919	3,612	1,681
Trail use	51	18,414	394	776	1,451	670
Winter activities	2	1,932	36	66	124	58
Big game hunting	7	2,515	62	127	249	112
Small game hunting	5	1,185	30	61	119	53
Other game hunting	1	201	5	10	20	9
Fresh water fishing	17	5,074	127	256	492	224
Nonconsumptive wildlife	39	9,611	239	486	963	427
Nonresident						
Developed camping	11	13,692	299	574	1,085	508
Mechanized travel	123	322,859	6,751	12,792	23,888	11,360
Other	32	56,234	1,207	2,316	4,350	2,049
Trail use	49	98,399	2,111	3,976	7,411	3,525
Winter activities	6	13,299	258	471	851	423
Big game hunting	5	3,766	94	191	379	168
Small game hunting	4	2,395	59	121	239	106
Other game hunting	1	996	25	50	100	44
Fresh water fishing	33	19,067	472	946	1,841	830
Nonconsumptive wildlife	45	27,414	688	1,405	2,782	1,238
Total	571	704,812	15,230	29,280	55,144	25,886

Table 10.9—Allocation of tourism from TTSA methods to sectors, 1997

IMPLAN sector		Direct sector 1997 values from IMPLAN					Tourism allocation by sector		
Name	Number	Employment	Employee compensation	Value added	Industry output	Total regional product	Leisure tourism	Gross outdoor recreation[a]	Outdoor recreation[b]
		Jobs	*Dollars (millions)*				*Percent*		
Hotel and lodging	463	492,002	9,047	15,309	25,595	13,698	34.1	6.5	11.2
Eating and drinking places	454	2,144,731	24,807	37,248	73,953	32,195	9.7	1.9	3.2
Taxi	434	82,788	1,576	2,071	535	2,029	19.0	3.6	6.3
Bus	510	11,183	495	-540	3,190	-540	20.0	3.8	6.6
Domestic airlines	437	309,060	14,096	20,504	35,958	18,646	34.0	6.5	11.2
Automobile rental	477	84,679	1,699	4,625	7,512	4,108	13.0	2.5	4.3
Tours and arrangements	439	66,092	1,618	2,958	4,488	2,853	20.0	3.8	6.6
Recreation and entertainment	487	27,274	484	1,159	2,227	842	20.0	3.8	6.6
	488	329,106	4,543	8,664	13,802	8,063	20.0	3.8	6.6
Participant sports	485	20,046	190	319	589	281	22.0	4.2	7.3
	489	141,076	1,933	2,354	5,383	2,252	22.0	4.2	7.3
Movie and theater	483	119,323	1,713	2,384	9,785	2,310	15.0	2.9	5.0
	484	42,399	900	1,429	3,919	1,340	15.0	2.9	5.0
Sports events	486	22,745	1,170	1,519	1,588	1,449	7.0	1.3	2.3
Gas and oil	451	713,175	18,514	32,254	41,060	25,601	6.0	1.1	2.0
Automobile repair and parking	479	274,830	5,023	10,827	23,012	9,956	1.5	.3	.5
Other personal consumption expenditures (nondurables)	448	292	6,285	10,492	12,556	8,458	3.0	.6	1.0
	449	804,896	11,842	19,964	27,065	15,578	3.0	.6	1.0
	450	1,066,937	15,484	26,351	31,119	21,308	3.0	.6	1.0
	452	324,263	4,218	7,951	11,582	6,074	3.0	.6	1.0
	453	310,144	6,203	10,571	13,942	8,312	3.0	.6	1.0
	455	1,224,501	14,810	28,453	34,862	22,799	3.0	.6	1.0
	456	478,356	18,094	53,027	72,319	51,393	3.0	.6	1.0
Total		9,089,898	164,743	299,893	456,042	259,005			

[a] Assumes 19 percent.
[b] Assumes 33 percent.

Table 10.10—Direct effects by sector from TTSA methods recreation impact analysis, 1997

Sector	Employment	Employee compensation	Value added	Total industry output	Gross regional product
		- - - - - - - - *Dollars (millions)*			- - - - - - - - -
Assuming 19 percent of leisure tourism is outdoor recreation					
Hotel and lodging	31,853	586	991	1,657	887
Eating and drinking places	39,723	459	690	1,370	596
Bus and taxi	6,321	140	100	260	98
Airlines	19,965	911	1,325	2,323	1,205
Automobile rental	2,092	42	114	186	101
Tours and arrangements	4,651	114	208	316	201
Recreation and entertainment	25,079	354	691	1,128	627
Participant sports	12,474	164	207	462	196
Movie and theater	8,535	138	201	723	193
Sports events	560	29	37	39	36
Gas and oil	15,056	391	681	867	540
Automobile repair and parking	1,450	27	57	121	53
Other PCE	44,432	812	1,655	2,147	1,414
Total	212,193	4,166	6,958	11,600	6,145
Assuming 33 percent of leisure tourism is outdoor recreation					
Hotel and lodging	55,324	1,017	1,721	2,878	1,540
Eating and drinking places	127,765	1,478	2,219	4,405	1,918
Bus and taxi	10,979	244	174	452	170
Airlines	34,677	1,582	2,301	4,034	2,092
Automobile rental	3,633	73	198	322	176
Tours and arrangements	8,078	198	362	549	349
Recreation and entertainment	43,558	614	1,201	1,959	1,088
Participant sports	21,665	285	359	803	341
Movie and theater	14,825	240	349	1,256	335
Sports events	973	50	65	68	62
Gas and oil	26,150	679	1,183	1,506	939
Automobile repair and parking	2,519	46	99	211	91
Other PCE	77,172	1,411	2,875	3,730	2,455
Total	427,317	7,916	13,106	22,174	11,555

will lead to geographic shifts in economic costs and benefits, but may or may not represent an economic loss. For some sites, such as Great Smoky Mountains National Park, there may be no acceptable substitutes, in which case the loss of this location would clearly represent a loss in welfare, even if there were no loss in expenditures. To our knowledge, no systematic study of the joint production aspects of the forest landscape in supporting both the wood products and recreation/tourism industries has been conducted.

While much of the past controversy centers around public land, the management of private forests is becoming more controversial. Landowners and recreationists have similar perceptions about general forest management, but differing perceptions about harvesting activities (Marcouiller and Mace 1999, Theodori and others 2000). These differences also occur when comparing second homeowners with local residents (Marcouiller and others 1999).

Another source of discussion regarding the two forest uses is the disparity between the average annual incomes from the two sectors (table 10.16). The wood products average is higher than the Southwide economy average, which is higher than the average of the three recreation methods used. Average income per job (not a wage rate) ranges from less than $5,000 per year for timber to over $52,000 per year for pulp and paper. GRP per job, also shown in table 10.16, is highest for pulp and paper (over $82,000 per year) and lowest for wood furniture and recreation (about $33,000 per year).

Recreation and wood products contribute to the local community by providing jobs and income. However, both recreation and wood products development, on either public or private forest land, have the potential for negative effects on the local community. Murdy and others (2000) list some of the negative effects from recreation as host-tourist conflicts, crime, overcrowding, migration, and loss of family traditions. Negative impacts of wood products development could include resource ownership concentration (Bliss and others 1998a, 1998b; Joshi and others 2000; Swanson 1988) and externalities such as pollution, traffic, and resource alteration.

Distributional Consequences of Forest-Based Economic Activity

This section summarizes previous research on the distributional impacts of policies, industrial changes, and situations. In assessing situations, we can only examine correlations or associations, because causality between forests, forest-based industries, and distribution has not been determined.

Impact of a project or situation can be assessed by assuming individuals maximize utility consisting of physical, amenity, financial/economic, and institutional/social factors (Xu 1994). Impacts on groups divided by age, generation, income, geography, place in the production chain (producers or consumers), and race can all be assessed. In this discussion, we focus on financial and economic impacts on groups divided by geography (urban/rural), race, and income class, largely because these are what previous studies have addressed.

Previous analyses of distributional impacts in forestry have focused on the (1) public land harvests and (2) tree planting programs (Berck and others 1992, Boyd and Hyde 1989, Wear

Table 10.11—Total impacts (direct+indirect+induced) by sector from TTSA methods recreation impact analysis, 1997

Sector	Employment	Employee compensation	Value added	Total industry output	Gross regional product
		- - - - - - - - Dollars (millions) - - - - - - - - -			
Assuming 19 percent of leisure tourism is outdoor recreation					
Hotel and lodging	58,733	1,229	2,207	3,695	1,993
Eating and drinking places	60,277	967	1,674	3,170	1,481
Bus and taxi	11,773	285	383	775	354
Airlines	49,899	1,713	2,859	5,040	2,602
Automobile rental	4,521	104	230	388	206
Tours and arrangements	8,994	234	425	676	399
Recreation and entertainment	41,866	753	1,454	2,432	1,320
Participant sports	21,360	375	628	1,169	578
Movie and theater	21,313	431	757	1,760	703
Sports events	1,083	42	62	81	58
Gas and oil	25,297	642	1,170	1,702	983
Automobile repair and parking	3,223	73	143	275	130
Other PCE	71,033	1,407	2,918	4,038	2,684
Total	379,373	8,254	14,909	25,199	13,492
Assuming 33 percent of leisure tourism is outdoor recreation					
Hotel and lodging	102,011	2,134	3,832	6,417	3,461
Eating and drinking places	193,875	3,109	5,386	10,195	4,762
Bus and taxi	20,448	495	665	1,346	615
Airlines	86,667	2,975	4,965	8,753	4,519
Automobile rental	7,853	180	399	674	359
Tours and arrangements	15,621	406	737	1,174	694
Recreation and entertainment	72,714	1,309	2,525	4,223	2,293
Participant sports	37,098	652	1,091	2,030	1,004
Movie and theater	37,017	748	1,315	3,057	1,222
Sports events	1,881	72	108	140	101
Gas and oil	43,937	1,115	2,033	2,957	1,708
Automobile repair and parking	5,598	126	248	478	226
Other PCE	123,374	2,444	5,068	7,013	4,663
Total	748,094	15,765	28,372	48,456	25,624

and Hyde 1992). In addition, several analyses of the impacts of changes in the industry (products of technology) have been conducted (Alavalapati and others 1999, Marcouiller and others 1995, Xu 1994). Other studies have assessed the association between forests, rural communities, and the economic benefits derived from forests, including tourism and wood products (Bliss, J.C.; Bailey, C.; Howze, G.R.; Teeter, L.J. [n.d.] Timber dependency in the American South. SCFER Work. Pap. 74. 18 p. Unpublished manuscript. On file with: USDA Forest Service, Southern Research Station, Southeastern Center for Forest Economics Research, P.O. Box 12254, Research Triangle Park, NC 27709.) (Bliss and others 1994, 1998b; English and others 2000; Lee and Cubbage 1994; Overdevest and Green 1994).

Rural communities are found to be worse off than more urban communities, with lower per capita incomes, lower educational attainment, and higher unemployment (Beaulieu and others 2001, Gale and McGranahan 2001, Ghelfi 2001, Gibbs 2001, McGranahan 2001, Rowley and Freshwater 1999). This disparity is attributed, in part, to a lack of both human capital (education) and human-made capital (buildings and machinery), even in the presence of a wealth of natural capital (Beaulieu and others 2001). Social capital and other community attributes can also influence well-being in rural communities (Bliss, J.C.; Bailey, C.; Howze, G.R.; Teeter, L.J. [n.d.] Timber dependency in the American South. SCFER Work. Pap. 74. 18 p. Unpublished manuscript. On file with: USDA Forest Service, Southern Research Station, Southeastern Center for Forest Economics Research, P.O. Box 12254, Research Triangle Park, NC 27709.) (Force and others 2000).

Forests in the South are a major component of the region's natural capital, but forests are often associated with the absence of human and human-made capital (Joshi and others 2000). Forests are unlikely causes for lower economic well-being, but the negative associations and correlations between well-being and forests have been well documented (Bliss, J.C.; Bailey, C.; Howze, G.R.; Teeter, L.J. [n.d.] Timber dependency in the American South. SCFER Work. Pap. 74. 18 p. Unpublished manuscript. On file with: USDA Forest Service, Southern Research Station, Southeastern Center for Forest Economics Research, P.O. Box 12254, Research Triangle Park, NC 27709.) (Bliss and others 1994, Lee and Cubbage 1994, Overdevest and Green 1994). Berck and others (1992) found that problems in rural communities resulted more from remote locations and transportation costs than from specific forest products industries. Using simulation, they found that maximizing the diversity of the rural community or replacing wood products with other manufacturing sectors did not improve the economic well-being of the community.

Use of private forests for timber and recreation production could also have potentially undesirable distributional consequences. According to Marcouiller and others (1995), because forest land is owned by middle and upper income households, revenue from uses will go to these households. Alavalapati and others (1999), in a study in Canada, found that subsequent wood processing, however, leads to benefits for lower income households through increases in well-paid job opportunities (Alavalapati and others 1999). In contrast, increasing recreation

Table 10.12—Allocation of tourism from TIA methods to States, 1997

State	Tourism allocation by State					Totals for 1997 tourism from TIA		
	Leisure tourism	Forest	Leisure tourism-forest adjusted	Tourism in outdoor recreation—19%	Tourism in outdoor recreation—33%	Employment	Payroll	Travel expenditures
	Percent					*Jobs*	*Dollars (millions)*	
AL	43.0	67.2	49.0	9.3	16.2	72,000	976	4,180
AR	43.0	56.3	41.0	7.8	13.5	55,700	714	3,337
FL	43.0	46.7	34.0	6.5	11.2	794,000	14,235	52,135
GA	43.0	65.5	47.7	9.1	15.7	231,900	5,419	12,637
KY	43.0	49.8	36.3	6.9	12.0	99,700	1,967	4,734
LA	43.0	47.8	34.8	6.6	11.5	113,200	1,689	7,328
MS	43.0	61.5	44.8	8.5	14.8	74,000	1,177	3,806
NC	43.0	61.4	44.7	8.5	14.8	192,400	3,424	10,731
OK	43.0	17.4	12.7	2.4	4.2	68,100	1,313	3,505
SC	43.0	65.3	47.6	9.0	15.7	112,900	1,571	6,546
TN	43.0	53.9	39.3	7.5	13.0	167,400	3,621	8,985
TX	43.0	10.9	8.0	1.5	2.6	514,100	10,578	29,247
VA	43.0	62.9	45.8	8.7	15.1	201,800	3,528	11,627

production is likely to produce lower paying jobs locally, with the returns to capital accumulating to higher income households elsewhere. Adding race into the mix (rural, forested, and large minority populations) makes it harder to correct problems of lower human and human-made capital and often exacerbates the regressive distributional effects of rural, forested locations (Bliss and others 1994). Changes in the nature of the wood products sectors can also have distributional impacts. In modeling an expansion of the pulp and paper sector, Alavalapati and others (1999) found that higher income households benefited, while a decline in the lumber sector hurt higher income households more than lower income households.

Revenues and Expenditures by State and Federal Governments for Forest-Based Activities

State governments—State and local governments derive revenues from and make expenditures for both wood products and forest-based recreation and tourism. Expenditures include State budgets for forestry and park agencies and for visitor and tourism agencies, as well as grants or subsidies to specific industries or businesses designed to bolster economic development. Subsidies can include property tax or development fee waivers, infrastructure improvements or other incentives. These subsidies and grants are not usually focused on the forest-based sectors. In addition, the Federal Government may also provide subsidies through infrastructure improvements or development assistance.

Tables 10.17 and 10.18 show the revenues and expenditures of the 13 State forestry agencies for 1998 obtained from the National Association of State Foresters. Florida, Georgia, and North Carolina have the largest State forestry agencies. Over 54 percent of the expenditures for all States are for fire management. About 7 percent of revenues are from the Federal Government, and the remainder are from State budgets and sales or permits.

State-level expenditures in support of and revenue from forest-based recreation occur through both State park agencies and State travel and tourism agencies. Travel and tourism agencies, however, also deal with significant nonforest-recreation opportunities. Table 10.19 shows State park acres, expenditures, and revenues for the State parks in the 13 Southern States (Thoreau Institute 1995). Florida has the largest percentage of land in State parks, while Kentucky and Tennessee have the largest numbers of visitors.

Federal Government—The Federal Government contributes to the forest-based economy of the South, and hence to the general economy, through the management of Federal land used for recreation, hunting, and product removal. The harvest from national forests is discussed in more detail in the section on "Relationship between recreation and wood products sectors in the economy."

Land managed by the four major Federal land management agencies constitutes 4.7 percent of southern land area (tables 10.20 and 10.21). Most of this land is managed by the USDA Forest Service (Vincent and others 2001). This compares to the nearly 29 percent of total U.S. land area that is managed by these agencies. Arkansas, Virginia, and North Carolina have the largest percentage of Federal land among Southern States, while Texas, Oklahoma, and Alabama have the smallest. Table 10.19 also shows acres of wilderness by agency and miles of wild, scenic, and recreational rivers by agency. Wilderness represents over 10 percent of Federal land in the South, with most of the wilderness occurring in Florida, Virginia, North Carolina, and Arkansas.

Timber is produced on forest land managed by the USDA Forest Service,

Table 10.13—Direct and total impacts from TIA methods of recreation impact analysis, 1997

	Percent of tourism in outdoor recreation					
	19 percent			33 percent		
State	Employment	Payroll	Expenditures	Employment	Payroll	Expenditures
	Jobs	*Dollars (millions)*		*Jobs*	*Dollars (millions)*	
			Direct			
Alabama	12,410	168	720	21,555	292	1,251
Arkansas	8,036	103	481	13,957	179	836
Florida	95,121	1,705	6,246	165,211	2,962	10,848
Georgia	38,926	910	2,121	67,609	1,580	3,684
Kentucky	12,726	251	604	22,103	436	1,049
Louisiana	13,869	207	898	24,088	359	1,559
Mississippi	11,675	186	600	20,278	323	1,043
North Carolina	30,288	539	1,689	52,606	936	2,934
Oklahoma	3,036	59	156	5,273	102	271
South Carolina	18,897	263	1,096	32,822	457	1,903
Tennessee	23,136	501	1,242	40,183	869	2,157
Texas	14,384	296	818	24,983	514	1,421
Virginia	32,529	569	1,874	56,498	988	3,255
South	315,034	5,755	18,547	547,165	9,996	32,213
		Total (direct+indirect+included)				
Alabama	25,791	511	1,715	44,795	888	2,978
Arkansas	17,236	342	1,146	29,937	594	1,990
Florida	223,601	4,435	14,865	388,360	7,702	25,818
Georgia	75,942	1,506	5,049	131,899	2,616	8,769
Kentucky	21,632	429	1,438	37,571	745	2,498
Louisiana	32,141	637	2,137	55,824	1,107	3,711
Mississippi	21,498	426	1,429	37,338	741	2,482
North Carolina	60,476	1,199	4,020	105,037	2,083	6,983
Oklahoma	5,595	111	372	9,717	193	646
South Carolina	39,225	778	2,608	68,128	1,351	4,529
Tennessee	44,456	882	2,955	77,213	1,531	5,133
Texas	29,295	581	1,948	50,882	1,009	3,383
Virginia	67,097	1,331	4,461	116,537	2,311	7,747
South	663,984	13,168	44,142	1,153,236	22,871	76,668

the Bureau of Land Management, the FWS, and the National Park Service. All four agencies contribute substantial recreation opportunities. Mining and oil and gas production occur on some Federal lands in these States. Some of the land included in table 10.20 is not forested, such as coastal marshlands and grasslands managed by the agencies. Note also that these values are for Texas and Oklahoma, in their entirety.

Management of public land also contributes to local economies through expenditures made by the agencies and through payroll for employees. For example, the USDA Forest Service contributed over $330 million to the Southern Region for management of the national forests, for research and development, for State and Private Forestry, and for payments to States. Revenues generated from activities on Federal lands are shared with local governments through various regulations, including the 25 Percent Fund Act (Public Law 60-136) and Payments in Lieu of Taxes (PILT) (Public Law 94-565, Public Law 97-258). In 1996, the USDA Forest Service, through the 25 percent fund, paid $22,709,317 to Southern States. This total does not include PILT payments or payments made through the Minerals Management Service, Department of the Interior.

Recently, these laws were amended by the Secure Rural Schools and

Table 10.14—Comparison of NFS, TTSA, and TIA recreation impacts, 1997

Method	Visitor days	Employment	Employee compensation	Value added	Total industry output	Gross regional product
	Million	*Jobs*	*- - - - - Dollars (millions) - - - - -*			
Direct impacts						
NFS-participation	317	136,944	2,485	4,467	8,973	3,805
NFS-land	878	379,116	6,879	12,366	24,840	10,533
TTSA-19	492	212,193	4,166	6,958	11,600	6,145
TTSA-33	990	427,317	7,916	13,106	22,174	11,555
TIA-19[a]	730	315,034	5,755	6,890	18,547	20,360
TIA-33[a]	1,268	547,165	9,996	11,968	32,213	35,361
	Million	*- - - - - Percent - - - - -*				
Southern economy						
NFS-participation	317	.34	.23	.24	.27	.22
NFS-land	878	.95	.63	.66	.74	.61
TTSA-19	492	.53	.38	.37	.35	.35
TTSA-33	990	1.07	.72	.70	.66	.67
TIA-19[a]	730	.79	.53	.63	.55	.61
TIA-33[a]	1,268	1.37	.91	1.09	.96	1.05
	Million	*Jobs*	*- - - - - Dollars (millions) - - - - -*			
Total impacts (direct+indirect +induced)						
NFS-participation	317	254,591	5,501	10,577	19,919	9,350
NFS-land	878	704,812	15,230	29,280	55,144	25,886
TTSA-19	492	379,373	8,254	14,909	25,199	13,492
TTSA-33	990	748,094	15,765	28,372	48,456	25,624
TIA-19[a]	730	663,984	13,168	15,765	44,142	48,456
TIA-33[a]	1,268	1,153,236	22,871	27,382	76,668	84,160
	Million	*- - - - - Percent - - - - -*				
Southern economy						
NFS-participation	317	.64	.50	.56	.59	.54
NFS-land	878	1.76	1.39	1.55	1.64	1.49
TTSA-19	492	.95	.75	.79	.75	.78
TTSA-33	990	1.87	1.44	1.50	1.44	1.48
TIA-19[a]	730	1.66	1.20	1.44	1.32	1.44
TIA-33[a]	1,268	2.88	2.09	2.50	2.29	2.51

[a] Estimates were made for value added and gross regional product for the TIA methods using the relationship between TTSA employee compensation and value added and between total industry output and gross regional product.

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Community Self Determination Act of 2000 (Public Law 106-393). Counties that have received payments previously are now eligible to collect either the traditional amount (usually 25 percent for USDA Forest Service land) or an amount equal to the average of the three highest years' payments between 1986 and 1999. If the latter amount is requested (referred to as the "full payment"), the counties must use 80 to 85 percent of the total for traditional payments to support roads and schools. The percentage depends on the total amount received. The balance of the payment would be used for public land projects or county-level projects as determined by a resource advisory council in the local area. This new law was to take effect for the fiscal year 2001 payments to States.

Discussion and Conclusions

Forests are important in the local and regional economies of the South, contributing jobs, income, and other less tangible benefits. The overall southern economy has grown since 1969 with increases in numbers of jobs

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proportionate to increases in population and in the national economy. This new economy is less dominated by manufacturing and agriculture, with continuing shifts into the retail and service sectors. Timber and agriculture, the two major uses of rural southern land, still account for over 6 percent of the southern economy. Much of the South is still rural and poor, though conditions have improved.

The South has 33 percent of the U.S. population and 24 percent of the U.S area, but only 4 percent of Federal land and 12 percent of State park and forest land. About 2.6 percent of U.S. wilderness is in the South, and 6.8 percent of miles of wild, scenic, and recreational rivers are in the 13 Southern States. These percentages imply that both recreational and timber producing opportunities may be more constrained on public land in the South than in other regions of the United States. National forests in the Southern Region are the second most heavily used for recreation among the nine USDA Forest Service regions, with visits of 1.9 per acre, reflecting the scarcity of public land for outdoor recreation in this region. National forests contributed 1.7 percent of the value of timber harvested, and an estimated 17 percent of outdoor recreation-based tourism in 1997. Fourteen southern counties have high concentrations of wood products employment and high percentages of land managed by the USDA Forest Service.

The U.S. wood products industry continues to concentrate in the South, which already has 39.3 percent of U.S. wood products jobs. Concentrations of both the lumber and wood products sector and the pulp and paper sector have increased since 1969, while the furniture sector concentration decreased. The percentages of State-level jobs and income in wood products have generally declined since 1969, but actual numbers of jobs have remained fairly constant. Tourism-related industries are increasing in the South, but are not becoming more concentrated in the South. The percentage of State-level jobs and income in the tourism-related sectors is increasing in all 13 States, as are the actual numbers of jobs and amount of income.

Table 10.15—National forest acres, visitation, and visits per acre for all regions, 2000

Region	Acres	Visits	Visits per acre
	Million		
Northern	25.4	12.4	0.49
Rocky Mountain	22.1	38.6	1.75
Southwest	20.8	17.3	.83
Intermountain	32.0	20.5	.64
Pacific Southwest	20.1	20.2	1.00
Pacific Northwest	24.7	34.0	1.38
Southern	13.2	24.9	1.89
Eastern	12.0	34.2	2.85
Alaska	22.0	7.0	.32
United States	192.3	209.1	1.09

Source: National Visitor Use Monitoring Report, USDA Forest Service, 2001; Lands of the USDA Forest Service, 2001.

Table 10.16—Income, value added, total industry output, and gross regional product per job for wood products and recreation sectors and Southwide, 1997

Sector	Direct effects per job: Employee comp.	Value added	Total industry output	Gross regional product
	Dollars (millions)			
Aggregate wood products sector				
Timber	4,691	70,137	130,154	59,659
Logging	23,935	59,674	160,203	58,728
Sawmills	27,308	41,942	119,609	41,245
Wood furniture	26,748	34,249	96,385	33,721
Pulp and paper	52,632	85,279	263,083	82,519
Wood products avg.	32,402	53,614	153,538	51,910
Recreation method				
NFS based	21,608	41,543	78,240	36,727
TTSA	19,633	32,793	54,666	28,960
TIA	18,223	NA	58,471	NA
Recreation method avg.	19,821	37,168	63,792	32,844
Southwide average	27,370	47,147	83,866	43,412

NA = not applicable.
Source: IMPLAN 1997.

In 1997, wood products sectors contributed 5.5 percent of southern jobs and 6.0 percent of GRP. Public lands represented 8.5 percent of this contribution. In 1997, outdoor recreation-based tourism contributed between 0.64 and 2.88 percent of southern jobs and between 0.51 and 2.51 percent of GRP. Public lands represented approximately 56 percent of this contribution.

Both forest-based recreation and wood products rely on the nearby presence of forest land. Thus, these

Table 10.17—Revenue sources by State for forestry activities in 1998

State	Government sources			Revenue				
State	Federal	State	Other	Sales	Permits	Service charges	Other	Total
	Dollars (thousands)							
Alabama	2,973	11,968	2,233	1,668	2	229	6,450	25,523
Arkansas	1,195	5,915	5,959	1,657		76	96	14,898
Florida	2,811	46,300	700	4,700	1,500			56,011
Georgia	2,443	34,612	1,366	2,900		664	16	42,001
Kentucky	1,421	8,462		370			482	10,735
Louisiana	1,180	9,225	761	1,962		554		13,682
Mississippi	130	19,800	5,300			350		25,580
North Carolina	3,279	33,027	5,219	1,929		1,246	5,351	50,051
Oklahoma	1,268	9,120	88	709		12	38	11,235
South Carolina	2,377	16,842		2,406	22	161	1,580	23,388
Tennessee	1,548	14,701	160	1,926		30	64	18,428
Texas	2,118	11,373		1,097			1,430	16,018
Virginia	1,993	12,309		2,334	34	353	4,872	21,895
Total	22,743	233,654	21,786	23,659	1,558	3,322	15,507	307,551

sectors are often concentrated in rural areas. Rural areas in the South are generally less well off, have higher minority concentrations, and more forest land. While causality between forests and well-being has not been determined, the associations between forested areas, wood products concentrations, and economic well-being indicate that rural, forested areas are less well off than many, but not all, other rural areas.

Needs for Additional Research

Research is needed to:

- Explore the joint production of recreation/tourism and wood products from forested landscapes and the subsequent economic impacts.
- Explore the relationship between growth in the economy, economic and social well-being, and eco-system sustainability.
- Continue to work to isolate the forest-based portion of recreation/tourism impacts on the economy.
- Improve methodologies and gather data to assess the total resource impacts of both wood products and forest-based tourism development through natural resource accounting.
- Develop comprehensive models and gather data to address distributional aspects of the forest-economy relationship.
- Explore potential for substitution between public and private lands in providing wood products and recreation/tourism outputs.

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Literature Cited

Abt, R.C.; Brunet, J.; Murray, B.C.; Roberts, D.G. 1994. Productivity growth and price trends in the North American sawmilling industries: an inter-regional comparison. Canadian Journal of Forest Research. 24: 139–148.

Alavalapati, J.R.R.; Adamowicz, W.L.; White, W.A. 1999. Distributional impacts of forest resource policies in Alberta. Forest Science. 45(3): 342–348.

Aruna, P.B.; Cubbage, F.W.; Abt, K.L.; Redmond, C. 1997. Regional economic contributions of the forest-based industries in the South. Forest Products Journal. July/Aug: 35–45.

Beale, C.L.; Johnson, K.M. 1998. The identification of recreational counties in nonmetropolitan areas of the U.S.A. Population Research and Policy Review. 17: 37–53.

Beaulieu, L.J.; Barfield, M.A.; Stone, K.L. 2001. Educated workforce, quality jobs: still elusive goals in the rural South. Rural America. 15(4): 28–35.

Table 10.18—Expenditures by State for forestry activities in 1998

State	Cooperative forestry and landowner assistance			Urban and community forestry		Fire mgmt.	State forest mgmt.	Marketing	Insect and disease	RC&D (PL-566)	Nursery	Forest recreation	Other	Total
	State programs	Forest Service	FSA/ NRCS	State programs	Federal programs									
	Dollars (thousands)													
AL	1,570	4,298	977		697	9,581	355	199	1,994		2,420		3,432	25,523
AR		3,491	472		262	6,555	329	5	195	46	1,109		1,606	14,070
FL	1,140	625	1,000		506	40,446	7,815	1	150	586	842	1,400	1,500	56,011
GA		1,242			909	31,787	461	506	330	35	2,059		4,672	42,001
KY	2,161		21		651	5,659	50	307	110	106	1,132		184	10,380
LA	1,884	318	282		308	7,540	44		214		1,962	290	840	13,682
MS	10,300	100	300		300	14,300	2,600		200		1,500		300	29,900
NC	12,589	123			324	25,846	456		2,081		1,970		6,660	50,049
OK	42	612	53	139	428	8,719		1	52	18	997		174	11,235
SC	846	46	94	165	320	13,755	3,648		616	28	1,638		2,229	23,385
TN	1,286	120	73	61	365	10,053	1,949	133	261		1,291		2,795	18,387
TX	5,117	692	450	839	589		50	522	1,139		823		346	10,567
VA	14,908	106	15		557	3,383	685	145	493	450	1,553			22,295
Total	51,842	11,773	3,737	1,204	6,216	177,623	18,442	1,819	7,835	1,269	19,296	1,690	24,738	327,485

Berck, P.; Burton, D.; Goldman, G.; Geoghegan, J. 1992. Instability in forestry and forestry communities. In: Nemetz, P.N., ed. Emerging issues in forest policy. Vancouver, BC: UBC Press: 315–338.

Bliss, J.C.; Howze, G.R.; Teeter, L.J.; Bailey, C. 1994. Forestry and poverty in Alabama's Black Belt. In: Wear, D.N., ed. Proceedings of the 1993 southern forest economics workshop. Durham, NC: Duke University: 221–227.

Bliss, J.C.; Walkingstick, T.L.; Bailey, C. 1998a. Development or dependency? Sustaining Alabama's forest communities. Journal of Forestry. 96(3): 24–30.

Bliss, J.C.; Sissock, M.L.; Birch, T.W. 1998b. Ownership matters: forestland concentration in rural Alabama. Society and Natural Resources. 11: 401–410.

Bowker, J.M.; English, D.B.K.; Cordell, H.K. 1999. Projections of outdoor recreation participation to 2050. In: Cordell, H.K., princ. invest. Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 323–351.

Boyd, R.G.; Hyde, W.F. 1989. Forestry sector intervention: the impacts of public regulation on social welfare. Ames, IA: Iowa State University Press. 295 p.

Cook, P.J.; Mizer, K.L. 1994. The revised ERS county typology: an overview. Rural Dev. Res. Rep. 89. Washington, DC: U.S. Department of Agriculture, Rural Economy Division, Economic Research Service. 48 p.

Cromartie, J.B. 2001. Migrants in the rural South choose urban and natural amenities. Rural America. 15(4): 7–18.

Deller, S.C.; Tsai, T-H.; Marcouiller, D.W.; English, D.B.K. 2001. The role of amenities and quality of life in rural economic growth. American Journal of Agricultural Economics. 83(2): 352–365.

English, D.B.K.; Marcouiller, D.W.; Cordell, H.K. 2000. Tourism dependence in rural America: estimates and effects. Society and Natural Resources. 13: 185–202.

Table 10.19—Revenues and expenditures by State for State park management

State	State park	State area in parks	Total visitors	User fee revenues	Operating budget	Capital budget	Total budget
	Ac (k)	*Percent*	*k*	*- - - - - - - - - - - - - Dollars (thousands) - - - - - - - - - - - -*			
AL	50	0.20	6,198	23,912	28,547	84	28,631
AR	48	.10	7,257	12,661	21,012	2,323	23,335
FL	428	1.20	11,416	19,196	43,858	14,100	57,958
GA	57	.20	15,637	18,475	37,832	4,525	42,357
KY	43	.20	28,396	40,800	57,672	10,906	68,578
LA	39	.10	1,221	2,141	6,511	2,675	9,186
MS	22	.10	3,913	5,196	11,909	1,562	13,471
NC	135	.40	11,830	2,238	11,956	2,839	14,795
OK	72	.20	16,049	17,240	27,664	1,349	29,013
SC	80	.40	8,189	12,034	19,919	3,871	23,790
TN	133	.50	28,701	21,033	36,216	0	36,216
TX	499	.30	25,368	15,178	36,093	10,289	46,382
VA	67	.30	3,779	2,350	11,122	5,767	16,889
Total	11,610		725,500	504,594	1,143,593	332,239	1,475,832
South (percent)	14.41		23.15	38.14	30.63	18.15	27.82

Force, J.E.; Machlis, G.E.; Zhang, L. 2000. The engines of change in resource-dependent communities. Forest Science. 46(3): 410–422.

Gale, F.; McGranahan, D.; 2001. Nonmetro areas fall behind in the "new economy". Rural America. 16(1): 44–52.

Ghelfi, L.M. 2001. Most persistently poor rural counties in the South remained poor in 1995. Rural America. 15(4): 36–49.

Gibbs, R. 2001. New South, old challenges. Rural America. 15(4): 2–6.

Joshi, M.L.; Bliss, J.C.; Bailey, C. [and others]. 2000. Investing in industry, underinvesting in human capital. Society and Natural Resources. 13(4): 291–319.

Kass, D.I.; Okuba, S. 2000. U.S. travel and tourism satellite accounts for 1996 and 1997. Survey of Current Business. July: 8–24.

Lee, K.J.; Cubbage, F.W. 1994. Timber dependent communities: how do they stack up? In: Wear, D.N., ed. Proceedings of the 1993 southern forest economics workshop. Durham, NC: Duke University: 214–220.

Marcouiller, D.W. 1998. Environmental resources as latent primary factors of production in tourism: the case of forest-based commercial recreation. Tourism Economics. 4(2): 131–145.

Marcouiller, D.W.; Green, G.R.; Deller, S.C.; Sumathi, N.R. 1999. Recreational homes and regional development: a case study from the Upper Great Lakes States. Publ. G3651. Madison, WI: University of Wisconsin. http://www1.uwex.edu/ces/pubs/pdf/G3651.PDF. [Date accessed: July 10, 2002].

Marcouiller, D.W.; Mace, T. 1999. Forests and regional development: economic impacts of woodland use for timber and recreation in Wisconsin. Publ. G3694. Madison, WI: University of Wisconsin. http://www1.uwex.edu/ces/pubs/pdf/G3694.PDF. [Date accessed: July 10, 2002].

Marcouiller, D.W.; Schreiner, D.F.; Lewis, D.K. 1995. Distributive economic impacts of intensive timber production. Forest Science. 41(1): 122–139.

McGranahan, D.A. 2001. New economy manufacturing meets old economy education policies in the rural South. Rural America. 15(4): 9–27.

Minnesota IMPLAN Group, Inc. 1997. IMPLAN professional social accounting and impact analysis software: user's, analysis, and data guide. Stillwater, MN: Minnesota IMPLAN Group, Inc. 378 p.

Morton, P.A. 1994. Charting a new course: national forests in the Southern Appalachians. Atlanta: The Wilderness Society. [Number of pages unknown].

Murdy, J.; Yiannakis, A.; Stuart, J. 2000. The perceived impacts of tourism: economic, environmental, and sociocultural influences of tourism on the host community. Kyle, Gerard, comp., ed. Proceedings of the 1999 northeastern recreation research symposium. Gen. Tech. Rep. NE–269. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 3–9.

National Association of State Foresters. 2001. http://www.Stateforesters.org/statistics/FY98_Statistics/Financial.htm. [Date accessed: January].

Nord, M.; Cromartie, J.B. 1997. Migration: the increasing importance of rural natural amenities. Choices. Third quarter: 31–32.

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Table 10.20—Acres managed by Federal agency by State, 1999

State	Total	Federal land		Managed by agency: USDA Forest Service	National Park Service	Fish and Wildlife Service	Bureau of Land Management	Total	Federally designated wilderness: USDA Forest Service	National Park Service	Fish and Wildlife Service	Bureau of Land Management
	- - - - - - - *Acres* - - - - - - -		%	- - - - - - - - - - - - - - - -	- - - - - - - -	- - - - - - -	- - - - - - -	- - - *Acres* - - -	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -
AL	32,678,400	1,109,546	3.4	665,026	16,873	57,866	110,963	41,367	41,367	0	0	0
AR	33,399,360	3,259,660	9.8	2,586,074	101,456	345,745	291,126	153,655	116,578	34,993	2,144	0
FL	34,721,280	2,889,080	8.3	1,152,824	2,443,323	976,080	25,277	1,422,247	74,495	1,296,500	51,252	0
GA	37,295,360	2,080,239	5.6	865,078	40,335	479,241	0	485,484	114,537	8,840	362,107	0
KY	25,512,320	1,235,647	4.8	693,746	93,941	7,487	0	16,779	16,779	0	0	0
LA	28,867,840	1,284,689	4.5	604,210	10,731	510,615	309,611	17,025	8,679	0	8,346	0
MS	30,222,720	1,774,075	5.9	1,158,967	107,866	223,634	57,171	10,683	6,046	4,637	0	0
NC	31,402,880	2,508,402	8.0	1,244,295	393,095	421,080	0	111,419	102,634	0	8,785	0
OK	44,087,680	1,280,559	2.9	397,131	10,200	167,682	2,126	23,113	14,543	0	8,570	0
SC	19,374,080	1,188,350	6.1	613,171	27,152	160,490	0	60,681	16,671	15,010	29,000	0
TN	26,727,680	1,643,374	6.1	634,523	355,354	114,517	0	66,349	66,349	0	0	0
TX	168,217,600	2,804,397	1.7	755,104	1,183,095	496,916	0	85,333	38,483	46,850	0	0
VA	25,496,320	2,299,111	9.0	1,660,428	333,422	129,721	0	177,214	97,635	79,579	0	0
South	538,003,520	25,357,129	4.7	13,030,577	5,116,843	4,091,074	796,274	2,671,349	714,796	1,486,409	470,204	0
U.S. total	2,271,343,360	654,885,389	28.8	192,046,672	77,937,494	93,628,302	264,174,745	104,231,201	34,777,793	43,229,874	20,694,502	5,529,032

Source: Congressional Research Service, 2001.

Overdevest, C.; Green, G.P. 1994. Forest dependence and community well-being: a segmented market approach. Society and Natural Resources. 9: 111–131.

Pennsylvania Department of Conservation and Natural Resources. 1999. Pennsylvania Outdoor Tourism: visitor profile and economic impact. http://www.dcnr.state.pa.us/recstudy/outdoortourism.html. [Date accessed: July 10, 2002].

Rowley, T.D.; Freshwater, D. 2000. Are workers in the rural South ready for the future? Rural Development Perspectives. 14(3): 27–35.

Schallau, C. 1994. The contribution of the forest products industry to rural economies of the Southern Appalachian region. Tech. Bull. 94–4. Washington, DC: American Forest and Paper Association. [Number of pages unknown].

Southern Appalachian Man and the Biosphere (SAMAB). 1996. The Southern Appalachian assessment social/cultural/economic technical report. Rep. 4 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 220 p.

Theodori, G.L.; Luloff, A.E.; Slack, T.A. 2000. Recreationists' attitiudes toward the forest and forest management policies. In: Kyle, Gerard, comp., ed. Proceedings of the 1999 northeastern recreation research symposium. Gen. Tech. Rep. NE–269. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 219–223.

Thoreau Institute. 1995. State acres, revenues, and expenses. http://www.ti.org/sparkdata.html. (Date accessed: November 5, 2001).

Travel Industry Association of America. 1999. Impact of travel on state economies. Washington, DC: Travel Industry Association of America. 88 p.

U.S. Department of Agriculture, Forest Service. 1988. The South's fourth forest: alternatives for the future. For. Res. Rep. 24. Washington, DC: U.S. Department of Agriculture, Forest Service. 512 p.

Table 10.21—Miles of wild, scenic, and recreational rivers by State, 1999

State	Wild	Scenic	Recreational	Total
	- - - - - - - - - - Miles	*- - - - - - - - - -*		
AL	36.4	25.0	0	61.4
AR	21.5	147.7	40.8	210.0
FL	32.7	7.9	8.6	49.1
GA	39.8	2.5	14.6	56.9
KY	9.1	0	10.3	19.4
LA	0	19.0	0	19.0
MS	0	21.0	0	21.0
NC	44.4	95.5	52.0	191.9
OK	0	0	0	0
SC	39.8	2.5	14.6	56.9
TN	44.3	0	1.0	45.2
TX	95.2	96.0	0	191.2
VA				0
South	363.0	417.0	142.0	922.0
U.S. Total	5,345.0	2,445.7	3,501.4	11,292.1

Source: Congressional Research Service (2001).

U.S. Department of Agriculture, Forest Service. 1999. Ozark-Ouachita highlands assessment: social and economic conditions. Rep. 4 of 5. Gen. Tech. Rep. SRS–34. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 299 p.

U.S. Department of Agriculture, Forest Service. 2001. National forest visitor use monitoring national and regional project results. http://www.fs.fed.us/recreation/programs/nvum/reports/year1/National_Report_Yr1.html. [Date accessed: July 10, 2002].

U.S. Department of Commerce, Bureau of the Census. 1998. U.S.A. counties [CD-ROM]. Washington, DC: U.S. Department of Commerce, Bureau of the Census.

U.S. Department of Commerce, Bureau of the Census. 2000a. U.S. Census Bureau: census historical poverty tables: CPH-L-162. Persons by poverty status in 1969, 1979, and 1989, by state. http://www.census.gov/hhes/poverty/census/cphl162.html. [Date accessed: July 2001].

U.S. Department of Commerce, Bureau of the Census. 2000b. U.S. Census Bureau: 1997 economic census: comparative statistics for United States, 1987 SIC basis.

http://www.census.gov/epcd/ec97sic/E97SUS.HTM. [Date accessed: July 2001].

U.S. Department of Commerce, Bureau of the Census. 2001. CPS: annual demographic survey: March supplement: table 4. residence and region by household relationship, race and Hispanic origin—poverty status of people in 1999.

http://ferret.bls.census.gov/macro/032000/pov/new04_016.htm. [Date accessed: July 22, 2002].

U.S. Department of Commerce, Bureau of the Census. 2002. U.S. Census Bureau: 2000 census. Population by poverty status in 1999 for counties: 2000, from census 2000 sample demographic profiles, table DP-3. http://www.census.gov/hhes/poverty/2000census/poppvstat00.html. [Date accessed: August 20, 2001].

U.S. Department of Commerce, Bureau of Economic Analysis. 1999. Regional Economic Information System. http://fisher.lib.virginia.edu/reis. [Date accessed: November 2000].

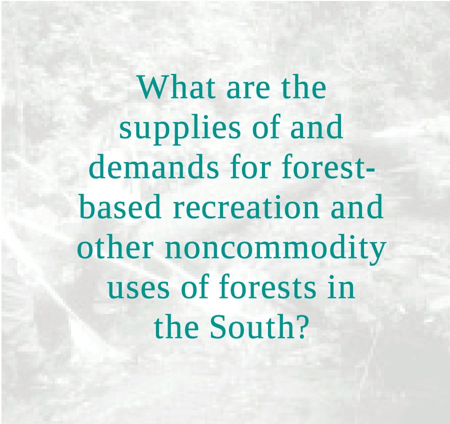
U.S. Department of the Interior, Fish and Wildlife Service. 1999. U.S. Census Bureau: national survey of fishing, hunting, and wildlife-associated recreation. http://www.census.gov/prod/www/abs/fishing.html. [Date accessed: December 2000].

U.S. Department of Labor, Bureau of Labor Statistics. 2000. Local area unemployment statistics. http://data.bls.gov/cgi-bin/srgate. [Series codes: LASSTXX000006, where XX is the state FIPS code for the 13 Southern States]. [Date accessed: December].

Vincent, C.H.; Cody, B.A.; Cope, M.L. [and others]. 2001. Federal land management agencies: background on land and resource management. Congressional Research Service Report to Congress, RL30867, February 27, 2001. http://www.cnie.org/nle/pub-17.pdf.

Wear, D.N.; Hyde, W.F. 1992. Distributive issues in forest policy. In: Nemetz, P.N., ed. Emerging issues in forest policy. Vancouver, BC: UBC Press: 297–314.

Xu, Zhi. 1994. Assessing distributional impacts of forest policies and projects: an integrated approach. Evaluation Review. 18(3): 281–311.



What are the supplies of and demands for forest-based recreation and other noncommodity uses of forests in the South?

Chapter 11: Forest-Based Outdoor Recreation

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Key Findings

■ At the top of the list of recreation activities in which southerners participate are walking for pleasure, attending family gatherings, visiting nature centers, sightseeing, driving for pleasure, picnicking, viewing or photographing natural scenery, and visiting historic sites. Very far down the list are high-technology, high-skill activities such as rock climbing and whitewater kayaking that often occupy much of the attention of forest recreation managers.

■ Participation in most outdoor recreation activities has been growing steadily over the last few years. Of forest-based activities, viewing and photographing fish, wildlife, birds, wildflowers, and native trees are among the fastest growing in the South. Other fast-growing activities include jet skiing, kayaking, day hiking, and backpacking.

■ To southerners, outdoor recreation is a highly important part of their lifestyles. But because of climate and type of forest setting, the abundance of forests in the South, in comparison with other less forested regions of the country, does not result in higher per capita forest recreation participation.

■ Thirty-one percent of residents of the South participate in gathering a wide variety of natural products, including nontimber forest products (NTFP). Most do so noncommercially. Sustaining availability of some NTFP resources will depend in large part on institutional capacities for education, monitoring, incentives, land management, and other conservation actions.

■ Numerous recreation opportunities of many types are available across the South. They are found in a wide variety of settings, ranging from large tracts of undeveloped land to highly developed theme parks in largely urban settings, both in public and private ownerships.

■ Of public ownerships, Federal tracts typically are large and mostly undeveloped. They fill a niche of providing back-country recreation. State parks and forests are usually smaller and more developed. They provide camping, picnicking, swimming, fishing, nature interpretation, and scenery.

■ The outdoor recreation supply potentials of public land will depend on policy evolution. On southern national forests, greater protection of roadless lands is likely, while at the same time recreation is increasingly finding its way to the tops of the priority lists of national forest managers. These trends are not as yet linked, but they should be by explicit policies. National parks will serve a different supply role because they are managed first to protect park resources, and secondly for public enjoyment. On U.S. Fish and Wildlife Service refuges, recreation is viewed as an incidental or secondary use and is not allowed unless it is directly related to a refuge's primary purpose.

■ While continuing to grow, adjust, and adapt, State government land systems, especially State parks, have reached a point of seeming maturity as a recreation resource, except for expansion of high-end resort developments which provide better sources of revenue.

■ Recreation access to private land is increasingly limited to the owners themselves, their families or friends, and lessees. The number of southern private owners allowing the public to recreate on their land has been decreasing.

■ Accommodating future public recreation demand increases will likely fall mostly to public providers, most of which will continue to face significant budget and capacity constraints. Some of this pressure would be reduced if private owners, the primary group of forest owners in the region, were willing to open more of their vast forested land holdings to public recreation. Current trends are not promising, however. Increasing demands for off-road vehicle use, hunting, fishing, and other of the more consumptive recreational activities are likely to bring about more conflicts between recreation participants and landowners.

■ As forest recreation demands grow, recreation activities are likely to conflict more with each other, especially on trails, in back country, at developed sites, on flat water (large rivers and lakes), in streams and whitewater, and on roads and their nearby environs. Typically a greater degree of conflict is perceived by one group of recreation users (usually traditional and nonmotorized users) than is perceived by other groups (usually nontraditional and mechanized/motorized users).

■ Depending on the characteristics of recreation use, the forest site, and site management, recreation can have a variety of impacts on soil, water, vegetation, and animal life. Almost all types of recreation activity have impacts, but this is especially so for motorized uses.

■ Forested areas in the South with heavy recreation pressures include the coastal Carolinas; coastal Florida; coastal Alabama, Mississippi, and Louisiana; the "Piedmont Crescent"; south-central Mississippi; the Ozark and Ouachita Mountains; and northeastern West Virginia.

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Introduction

This chapter overviews demands for and supplies of recreation and other nontimber uses of southern forests. We express demand in terms of the numbers of people who pursue various activities, including gathering NTFPs. In describing supply, we distinguish between public forests owned collectively by citizens and managed by government agencies at Federal, State, and local levels, and private forests owned by corporations or by individuals.

People are accustomed to paying little or nothing for recreation and other nontimber uses of the South's forests. At most, they may pay a small fee for an activity like camping. Typically, people pay nothing for the scenery or wildlife that makes camping, or any other activity, meaningful for them. But just because recreation activities for the most part are free does not mean they have no value. People often travel hundreds of miles to camp in just the right setting. And a birdwatcher may get inestimable joy from seeing a new species or from seeing a familiar species doing something unusual. Many, and possibly most, people would argue that recreation and other nontimber uses are the most important and highest valued uses of forests. The value of these uses is evident in the high demands for recreation opportunities in the region. As we report in this chapter, some of these demands are growing very rapidly.

In addition to addressing the general question of demand and supply, this chapter also addresses some specific questions raised during early public meetings where the Southern Forest Resources Assessment was described and discussed.

Methods

For the most part, estimates of demand and supply were obtained from published results of previous studies by the authors. These studies, or other sources used, are cited where that information is presented. In a few cases, special studies were necessary to answer some specific questions. The methods for these special studies are briefly described where their results are presented.

Results

Demand

Participation in outdoor recreation activities in the South and other regions of the country has been growing steadily over the last few years. Among the fastest growing activities are viewing and photographing nature, including fish, wildlife, flowers, and plant life (table 11.1). Number of people viewing and photographing fish almost doubled between 1995 and 2000. Gathering various forest products, such as berries, mushrooms, and herbs, also seems to be growing rapidly based on observed increases in visitation by forest managers. Various forms of boating such as kayaking and motorboating are also becoming increasingly popular.

Other activities growing almost as fast as boating activities include hiking, backpacking, bicycling, horseback riding, coldwater fishing, walking, and visiting nature centers. In addition to coldwater fishing, various other forms of fishing are growing in popularity, including warmwater fishing in lakes and lowland rivers. Further down the list, even camping and off-road driving are growing faster than the rate of population growth in the South. Hunting also is rising, but not nearly as rapidly as the activities already mentioned. Slower growing activities include motorboating, sightseeing, and waterskiing.

Across the Nation and the South, viewing, learning, and photographing activities have been adding enthusiasts the most rapidly. This fast growth in interest in viewing-learning activities and in demand for other activities brings both good and not so good tidings about the supply of recreation opportunities, as we discuss later in this chapter.

Topping the list of recreation activities in which southerners participate are walking for pleasure, attending family gatherings, visiting nature centers, sightseeing, driving for pleasure, picnicking, viewing or photographing natural scenery, and visiting historic sites (table 11.2). All these are traditional activities that require little specialized skill, equipment, or financial outlay, and their persistent growth has shown no signs of subsiding. Next in popularity are a series of viewing and photographing activities, fishing, gathering NTFPs, hiking, visiting wilderness, boating, and biking. Of these top 20 activities, only 2, fishing and gathering, consume forest resources, and only 2 are motorized. None of the activities listed below the top 20 are participated in by more than 20 percent of the South's population. Activities become increasingly specialized and expensive as one moves toward the bottom of the list.

The relative popularity of activities is approximately the same in the South as in the United States as a whole. However, across almost all activities, participation percentages for the South are lower than nationally. The principal exceptions are the water-based activities. Nevertheless, the percentages in column 2 of table 11.2 represent very large numbers of people seeking outdoor recreation opportunities in the South.

Demands for NTFPs

In early public meetings where this Assessment was discussed, requests were made for information about NTFPs. Research on such products and the effects of harvesting them from forests is in its infancy. The information presented here is from two sources: (1) the National Survey on Recreation and the Environment (NSRE) (Cordell, in press) and (2) published literature about individual products. Very little quantitative information is presented about the products because very little information is available.

The gatherers—The question asked in the NSRE survey was, "During the past 12 months, did you gather mushrooms, berries, firewood, or other natural products?" In the South, 31 percent of respondents reported

Table 11.1—Percent of the population participating, number of participants in outdoor activities, and percent change from 1995 to 2000, Southern Region

Activity	1995 partici-pation	Number of participants 1995	2000 partici-pation	Number of participants 2000	Change in number of participants 1995-2000
	Percent	*1,000s*	*Percent*	*1,000s*	*Percent*
Viewing or photographing fish	13.8	8,809.8	25.4	17,441.4	98.0
Jet skiing	5.7	3,638.8	10.4	7,141.4	96.3
Kayaking	1.1	702.2	1.9	1,304.7	85.8
Viewing or photographing wildlife	28.6	18,258.0	43.2	29,664.1	62.5
Day hiking	18.1	11,554.9	26.9	18,471.4	59.9
Backpacking	5.8	3,702.7	8.2	5,630.7	52.1
Bicycling	24.4	15,576.7	34.0	23,346.8	49.9
Horseback riding	7.5	4,787.9	10.3	7,072.7	47.7
Coldwater fishing	7.4	4,724.1	10.1	6,935.4	46.8
Walking for pleasure	64.2	40,984.6	82.0	56,306.9	37.4
Visiting nature centers, etc.	42.8	27,323.1	53.4	36,668.2	34.2
Freshwater fishing	26.7	17,045.0	33.2	22,797.4	33.7
Developed camping	17.2	10,980.3	21.3	14,626.1	33.2
Driving off-road	14.5	9,256.7	17.7	12,154.1	31.3
Visiting prehistoric sites	16.1	10,278.1	19.6	13,458.7	30.9
Family gathering	59.5	37,984.2	72.1	49,508.9	30.3
Viewing or photographing birds	26.3	16,789.7	31.4	21,561.4	28.4
Big game hunting	7.8	4,979.4	9.3	6,386.0	28.2
Warmwater fishing	24.9	15,895.9	28.7	19,707.4	24.0
Rafting	7.9	5,043.3	9.1	6,248.7	23.9
Swimming in lakes, rivers, ocean	27.4	23,875.8	42.4	29,114.8	21.9
Picnicking	44.0	28,089.2	49.6	34,058.8	21.3
Canoeing	6.7	4,277.2	7.5	5,150.0	20.4
Migratory bird hunting	2.5	1,596.0	2.7	1,854.0	16.2
Small game hunting	7.8	4,979.4	8.4	5,768.0	15.8
Sailing	3.7	2,362.0	3.9	2,678.0	13.4
Saltwater fishing	13.4	8,554.4	14.1	9,682.0	13.2
Primitive camping	12.8	8,171.4	13.1	8,995.4	10.1
Visiting historic sites	43.2	27,578.4	43.7	30,007.5	8.8
Motorboating	24.9	15,895.9	24.9	17,098.1	7.6
Rowing	3.0	1,915.2	3.0	2,060.0	7.6
Sightseeing	54.4	34,728.4	52.9	36,324.8	4.6
Waterskiing	9.7	6,192.4	8.6	5,905.4	(4.6)

Source: 1995 and 2000 National Survey on Recreation and the Environment (NSRE), USDA Forest Service, Athens, GA.

participating in natural products gathering. Of these, 54 percent did their gathering in a forest setting thus making the products they gathered NTFPs. Over 96 percent did their gathering for personal use; only 2 percent did it for income. Nine percent of gatherers collected mushrooms, 47 percent picked berries, 73 percent collected firewood, 35 percent collected rocks and minerals, 43 percent gathered tree materials, and 43 percent collected herbs and flowers. Among the many miscellaneous things gathered were insects, feathers, walnuts, arrowheads, gold, moss, pine needles, Spanish moss, water, wild honey, and seashells. Twenty-nine percent of those participating gathered on 3 or fewer days during the last 12 months; 34 percent gathered on 4 to 10 days; and about 11 percent gathered on 30 or more days.

Forty-two percent of those gathering natural products were male, 58 percent were female. Thirty percent were under age 35; 20 percent were 55 years or older. Eighty-six percent were white, 9 percent were black, 3 percent were Hispanic, 2 percent were American Indian, and the remaining, less than 1 percent, were Asian Americans. By income, the largest group (36 percent of gatherers) earned between $25,000 and $50,000 per year. The next largest group earned between $50,000 and $75,000 (about 17 percent). Those earning less than $15,000 per year made up just over 1 percent of all gatherers in the South, indicating that subsistence is not likely a motivating factor for most forest gathering. Forty-one percent of gatherers live in rural areas and 59 percent in urban areas. These percents differ greatly from the 80 to 20 percent split between urban and rural residence of people in the South. Almost 12 percent of gatherers had less than a high school education, and 59 percent had some college, including many who had earned their doctorate.

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Table 11.2—Percentages of the population participating in recreational activities in the South and Nation in 2001

Activity	South	United States
Walk for pleasure	83.08	84.85
Family gathering	71.91	73.85
Visit nature centers	53.69	59.27
Sightseeing	53.04	53.98
Driving for pleasure	52.77	53.66
Picnicking	49.73	57.34
View/photograph natural scenery	46.56	55.09
Visit historic sites	43.83	48.71
Swimming in lakes and streams	42.35	44.38
View/photograph wildlife	36.83	41.05
View/photograph flowers, etc.	36.68	41.19
Visit the beach	36.45	39.96
Bicycling	35.03	41.63
Gather mushrooms, berries, etc.	31.19	27.97
Visit a wilderness	31.11	35.45
Warmwater fishing	28.45	20.17
View or photograph birds	27.47	30.07
Day hiking	27.43	36.48
Visit a waterside besides the beach	27.07	27.09
Motorboating	24.86	23.90
View or photograph fish	21.39	21.68
Outdoor team sports	21.33	22.51
Developed camping	20.70	26.83
Visit prehistoric sites	19.53	21.30
Drive off-road	17.81	17.01
Mountain biking	16.15	23.39
Saltwater fishing	13.82	7.90
Primitive camping	13.05	16.18
Hunting	12.77	10.54
Horseback riding on trails	10.59	9.99
Coldwater fishing	10.37	14.37
Jet skiing	10.03	8.85
Rafting	9.16	9.95
Horseback riding on trails	8.87	8.09
Waterskiing	8.72	7.92
Backpacking	8.61	12.15
Canoeing	7.51	10.23
Snorkeling	6.13	6.95
Downhill skiing	4.37	10.26
Sailing	3.99	5.43
Rowing	3.31	4.99
Anadromous fishing	3.16	4.83
Migratory bird hunting	2.73	2.21
Scuba diving	2.14	1.77
Snowboarding	2.02	5.83
Kayaking	1.82	3.51
Surfing	1.48	1.52
Snowmobiling	1.36	7.06
Cross-country skiing	1.22	5.03
Windsurfing	.75	.85

Source: National Survey on Recreation and the Environment, USDA Forest Service, Athens, GA.

By State, percentages of residents who participated in gathering varied quite a bit. Alphabetically, percentages of State residents 16 years or older participating were: Alabama (31), Arkansas (22), Florida (24), Georgia (29), Kentucky (39), Louisiana (30), Mississippi (29), North Carolina (34), Oklahoma (34), South Carolina (27), Tennessee (40), Texas (29), and Virginia (44). By State, percentages whose participation was mainly in forests were: Alabama (63), Arkansas (69), Florida (56), Georgia (66), Kentucky (51), Louisiana (41), Mississippi (52), North Carolina (70), Oklahoma (41), South Carolina (43), Tennessee (55), Texas (39), and Virginia (59).

The products—Even though little quantitative data are available, it is obvious that gathering NTFPs is an important use of the South's forests. Such products are gathered for both personal and commercial uses. Because so little data are available on most nontimber products, this section focuses on two of the better known products, herbs and mushrooms.

■ ***Herbs*:** A number of herbs and other plants are gathered for personal use or sale. Some examples of plants reported to have medicinal properties are *Aloe barbadensis*, chamomile (*Matricaria recutita*), *Echinecea pallida*, American ginseng (*Panax quinquefolium*), and *Ginkgo biloba*. It has been estimated that herbal supplement sales in retail outlets in the United States in 1997 totaled $441 million (Blumenthal and others 1998). A national survey of alternative therapies published in Journal of the American Medical Association (JAMA) found that expenditures for alternative therapies increased by 45 percent between 1990 and 1997, to $27 billion in 1997. The kind of alternative therapies increasing most were herbal treatments (Eisenberg and others 1998).

■ ***Mushrooms*:** In this chapter we present information on the most important mushrooms collected. Most of the information about wild mushrooms was obtained from personal communication with Professor Orson K. Miller, Jr., a noted authority on southern mushrooms (Miller 1979), who provided a list of southern mushrooms favored by collectors. Wild mushrooms are described in "Edible Mushrooms of North

America" (Fischer and Bessette 1992), "Mushrooms of the Great Smokies" (Hesler 1960), and "Texas Mushrooms" (Metzler and Metzler 1992).

The more prominent of edible wild mushrooms of the South include ***Russula aeruginea***, which is a green-capped, distinctively colored mushroom with white gills that grows in hardwood forests. A close "cousin" is ***Russula virescens***, another green-capped mushroom, similar to ***R. aeruginea***, except that at maturity the cap shows cracks. ***Lactarius volemus*** is a reddish brown mushroom capped with whitish gills that is 2 to 5 inches wide. These mushrooms are considered choice edible wild mushrooms. Other favored mushrooms include the ***Cratarellus cornucopiodes/fallax***, commonly known as the Black Trumpet or Horn of Plenty. They are 2 to 5 inches across, trumpet shaped, and range from grayish to dark brown. They are highly valued for cooking. ***Hydnum repandum*** is commonly known as Sweet Tooth. It has a pale to rich orange cap and stalk, with pointed spines beneath the cap. Other wild mushrooms are collected, but these are among the main ones.

In addition to growing wild, a number of mushrooms are cultivated. Though cultivated, however, they are important as forest products, because most must be cultivated under forest cover. Others are cultivated in cut-log production systems. Shiitake, for example, are cultivated on dead hardwood trees in warm, moist environments. Much of North Carolina has been identified as ideal for shiitake production. In addition to shiitake, consumption of other specialty forest-grown mushrooms (including morels, oyster, and boletus) has been increasing for over a decade.

■ *Other NTFPs*: In addition to herbs and mushrooms, a wide variety of plants and parts of plants are harvested from within and on the edges of natural and disturbed forests (Chamberlain 1998). Leaves, twigs, vines, ferns, cones, fruits, bark, foliage, sap, firewood, poles, and boughs are collected. Edibles from forests include syrups, nuts, ramps, wild berries, and persimmons (Grafton 2000). Nonedibles include charcoal, chips, shavings, sawdust, and pine straw. Generally, too little information on these and other commercial and personal products exists to fully assess their supply and demand. But it is clear from the number of pamphlets, Web sites, and other emerging media that gathering, using, and selling NTFPs is rising across the South.

Several national organizations have been established to help maintain wild plant diversity, encourage understanding of threatened and endangered plant species, organize responsible wildcrafting, advance the interests of the herbal industry, and organize intergovernmental cooperation in managing land where nontimber products are gathered. Government agencies have highly significant roles in protecting vegetation and animals used as NTFPs. Each major public land agency (the Forest Service, National Park Service, and Fish and Wildlife Service) has or is currently developing a forest product-related policy. A joint Federal coalition for the management of wild plants has been developed to address issues related to overharvesting of wild medicinal plants on public and private land (http://www.nps.gov/plants/medicinal/). Recognizing that commercial demands may cause overharvesting in the wild, the Medicinal Plant Working Group, which includes representatives from industry, government, academia, tribes, and environmental organizations, aims to create a framework for discussion and action on behalf of conservation of medicinal plants.

Inventory of Outdoor Recreation Opportunities

Recreation opportunities of many types are available across the rural South and found across a variety of settings. Settings range from large tracts of undeveloped land to highly developed theme parks in urban settings. Our inventory was limited to rural settings to be consistent with the overall scope of this Southern Forest Resources Assessment. The source of data is the National Outdoor Recreation Supply Information System (Betz and others 1999). Because most of the data in this system are from secondary sources, it is not possible to separate forest from nonforest settings. The prevalence of forests on undeveloped land in the rural South, however, suggests that most of the opportunities reported here are, in fact, in forest settings.

Federal properties—There are an estimated 29.8 million acres of Federal land in the South, 4.6 percent of the Nation's total Federal land. This total includes 12.9 million acres in national forests, 5.4 million acres in national parks, 3.8 million acres in wildlife refuges, 0.8 million acres in Bureau of Land Management properties, 5.6 million acres in Army Corps of Engineers projects, 1.0 million acres in Tennessee Valley Authority projects, and 0.2 million acres in Bureau of Reclamation projects.

Federal water resources— Water resources in forest settings are a very significant component of recreation opportunities. Under Federal jurisdiction, many of these water resources are available as recreation opportunities. The U.S. Army Corps of Engineers manages over 2.6 million acres of water area in the region, most of it in reservoirs along river systems. To access these water areas, there are almost 1,400 boat ramps and 423 swimming areas. The National Park Service manages 234,000 acres of national rivers, 435,000 acres of national seashores and lakeshores, and 183 sites for swimming and boating. The Tennessee Valley Authority manages 18 reservoirs along the Tennessee River and a few of its tributaries. These reservoirs are highly significant as boating and other recreation activity destinations, including resorts. The Bureau of Reclamation manages 94,000 acres of water in the South, to which there is limited boating access. The USDA Forest Service manages over 260 boating sites and almost 100 swimming sites. The U.S. Fish and Wildlife Service manages 84 refuges that have boating access. Fishing is permitted in 83 of these refuges. Together these Federal water resources are highly important for outdoor recreation, and increasingly they are under pressures for use by different recreational interests.

The National Wilderness Preservation System—This system was established by Federal law in 1964. Managed in the South by the Forest Service, National Park Service, and Fish and Wildlife Service, over 2.6 million acres of Federal wildland in this region have been designated for this system. Just under 2.4 percent of our country's total land area is in designated protected wilderness. Six of the country's 50 States have no designated

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wilderness, but all of the Southern States do.

National recreation trails— This system includes highly scenic or otherwise recreationally significant trails. The South has almost 2,500 miles of national trails. Of these, 1,479 miles are on Federal land, over 400 are on State land, 279 are on local government land, and over 300 miles are on other land such as that of corporations and foundations.

Public campgrounds—Federal, State, and local governments operate 1,064 public campgrounds in the South. This number represents an increase from the 993 that existed in 1987. In these campgrounds are almost 90,000 individual campsites.

State land—Southern States provide 1.7 million acres for recreation in their State park systems and 3.6 million in their State forest systems. In State park systems are 858,600 acres in designated parks, 106,500 acres in recreation areas, 622,900 acres in natural areas, 29,100 acres in historic areas, 4,700 acres in environmental education areas, and 53,500 acres in miscellaneous other areas. The State park systems have an estimated 36,000 campsites, 2,562 cabins or cottages, 2,681 lodge rooms, 54 golf courses, 128 swimming pools, and 23 stables.

State scenic rivers—Thirty-two of the 50 State governments have river protection systems similar to the National Wild and Scenic River System. The South has 99 protected river segments with a total of nearly 2,500 miles of protected river settings. Louisiana has the largest of the region's State river protection programs.

Local government recreation supply—Data are less available for describing the role of local governments (county and municipal) in providing outdoor recreation opportunities, and the sources do not distinguish between urban and rural locations. The South has 896 municipal recreation departments, 416 county, 9 special district, and 40 miscellaneous others. These departments range in size from 1 part-time professional to over 50 full-time professionals, depending on size of population and service area. Opportunities are provided for picnicking, boating, fishing, hunting, swimming, biking, hiking, and nature study. A highly significant local role, in cooperation with Federal and State agencies, is the Rails-to-Trails program. With this program, abandoned rail corridors are converted to trail recreation uses. In the South in 1997, this program provided 101 trails with a total length of 669 miles. In addition, 241 new projects were underway that would add 3,560 miles of trails for nonmotorized uses.

Private forest land—In the South, almost 5 million private owners control nearly 190 million forested acres. The region has almost half of all the private forest land in the Nation. Fifty-five percent of the private land is owned by individuals. Only about 7 percent of this individually owned forest land (just over 13 million acres) is open for public recreation by people not connected in some way with the owner.

The Nature Conservancy—This private organization manages about 273,000 acres of natural land in the South. Of that total, about 102,000 acres are open for public recreation. The South has less Nature Conservancy land area than any other region of the United States.

Private campgrounds—About 1,850 privately owned and operated campgrounds are in the South. This total represents a decrease from 2,114 in 1987. These campgrounds have nearly 234,000 individual campsites—about 2 times the number of public campsites. Not only in the region, but also nationally, the number of private campgrounds and campsites decreased throughout the 1990s.

Private recreation businesses— The private sector provides recreation opportunities in a wide variety of ways. Except for campgrounds and day camps, the number of enterprises involved has grown over the last 15 years. For example, the number of guide and outfitter services has gone from just under 100 to over 350 in the South. Private enterprises make enormous contributions, especially as partners in providing facilities and services generally outside the mandates and authorities of government.

Potentials for Developing New Sources of Recreation Supply

The 2000 Renewable Resources Assessment of Outdoor Recreation and Wilderness (Cordell 1999) and public agency Web sites were the principal sources of information used to address this topic.

It seems clear that a great deal of forest land is suitable for uses that would expand the supply of recreation opportunities. Forests provide the natural settings sought by people for most land-based activities. The probability that a given piece of land will be used to expand supply, however, depends heavily on who owns it. Individual private owners may spend considerable sums to purchase and make a tract of rural land suitable for their own recreation, but they are not likely to spend much for the benefit of others. On public land, the prospects for expanding recreation opportunities depend on the mandates and policies of the managing agencies.

National forests—National forests in the South are significant contributors of forest recreation, but only in areas where national forests exist. Management has given greater emphasis to providing recreation opportunities over the last decade. The Secretary of Agriculture under the Clinton Administration announced a proposed plan for protecting nearly 60 million acres of roadless areas in national forests across the country, including nearly a half million acres in the South. Early in January 2001, President Clinton made perpetual protection of these roadless acres official policy of the Forest Service. Depending on how this decision is administered through the Bush Administration, this policy would:

- Eliminate most road construction and reconstruction on 445,000 acres of inventoried roadless areas on southern national forests.
- Limit timber harvesting to that needed for meeting defined stewardship objectives in roadless areas.
- Allow road construction only when necessary for public safety and resource protection.

Recreation is increasingly finding its way to the top of the priority lists for management of national forests. The Agency's National Recreation Strategy, approved by the Clinton Administration and applying to the entire Nation, is designed to:

- Assure sound stewardship of forest resources by making sure recreation activities are compatible with targets for sustaining ecosystem health.

- Provide safe, natural, well-designed, and well-maintained recreation opportunities for visitors.
- Provide opportunities for the public to learn about the values of conservation, land stewardship, and responsible recreation.

The Forest Service recognizes that maintaining high-quality landscape settings in the South is essential to providing high-quality recreation opportunities. The priorities for managing settings in the South, as well as across the Nation, as described in the national strategy, include:

- Identifying attributes of natural, social, and built environments essential for ecological sustainability and recreation opportunities. Recreation activities will be managed within the range of natural variability in ecosystem composition, structure, and function.
- Investing in some facilities and removing others. There is a standing need on national forests to upgrade facilities to meet health, sanitation, and accessibility standards, as well to remove buildings and infrastructure no longer needed.
- Emphasizing high-quality motorized opportunities and experiences, but managing motorized uses to maintain acceptable and balanced environmental impacts on trails and open forest areas.
- Reducing criminal activity and enforcing compliance with laws and regulations to protect forest settings.
- Working with local governments and private landowners to assure public rights-of-way onto national forests. As a part of this strategy, universal accessibility will become increasingly important (U.S. Department of Agriculture Forest Service 2000).

National parks—The National Park Service encourages recreation activities that (1) are consistent with its applicable legislation, (2) promote visitor enjoyment of parks, (3) are consistent with the protection of natural areas, and (4) are compatible with other park uses. Recreation activities that are usually allowed include boating, camping, bicycling, fishing, hiking, horseback riding, outdoor sports, picnicking, scuba diving, cross-country skiing, caving, mountain and rock climbing, and swimming. Aircraft use, off-road bicycling, hang-gliding, hunting, off-road vehicle use, and snowmobiling are covered by special regulations. The National Park Service manages recreation activities and southern park settings to protect park resources first, and then to provide for public enjoyment. Each park develops and implements visitor use management plans. Visitor use management plans contain specific, measurable management and resource protection objectives related to the activity or activities being addressed.

Unless mandated by statute, the National Park Service will not allow an activity if it would be inconsistent with the park's enabling legislation, nor if it would erode the values of or purposes for which the park was established. Unacceptable are activities that interfere with other visitor activities, consume park resources, impact natural processes, or endanger the welfare or safety of visitors.

Wildlife refuges—As in national parks, public recreation in fish and wildlife conservation areas must be compatible with refuge conservation purposes, and with any other primary objectives established by law or policy. Conservation areas include the National Wildlife Refuge System, national fish hatcheries, and other areas administered for fish and wildlife. Recreation is viewed as an incidental or secondary use of refuges. None of the refuges, hatcheries, game ranges, or other conservation areas allow forms of recreation not directly related to the primary purposes and functions of these areas.

The Division of Refuge Planning facilitates comprehensive planning on refuges. In this planning, the impacts of recreation visits are considered. Planning contributes to informed decisionmaking that recognizes the needs and interests of all parties, while keeping in sight the primary mission of the National Wildlife Refuge System.

Supply on State land—The South's State land has been an important source of outdoor opportunities for a long time, and it continues to be a highly important source. While never ceasing to grow, adjust, and adapt as times and demands change, State land systems, especially State parks, have seemed to reach a point of maturity (Landrum 1999). Little further expansion of park acreage is anticipated. What is expected is continued development of new facilities, especially the more upscale types, using more private than State capital, in order to draw visitors from greater distances and generate greater park revenues. Unlike Federal systems, States seem highly motivated to increase their in-State and out-of-State client base.

The greatest uncertainty facing State systems in the foreseeable future is unstable funding. Most seem likely to be required to generate an ever larger share of their operating budget through revenue-producing facilities, services, and programs. It is expected that State park systems especially will employ innovative measures to obtain sufficient funding to maintain or expand their operations. The challenge remains, however, for States to manage their land in ways that will maintain the quality of the outdoor recreation settings they offer, even as they plan to meet demands for fast-growing new activities.

Trail programs are highly significant in the makeup of most State programs. But managing State trail systems comes with a number of challenges. When asked in the National Survey of State Trail Administrators (Moore 1994), "What are the most significant roadblocks to getting and keeping trails on the ground in your State?" over one-fourth of the responding State officials identified funding as number one. Various threats to trails and connecting lands made up the next largest group of responses. Many trail administrators also reported that there was a major problem with lack of awareness of the value of trails and too little demonstrated support for trails by the public, by legislatures, and by State government in general.

When asked to identify the most pressing issues currently facing trails in their States, the most frequent responses related to specific threats to continued existence of trails and trail land. Many of these concerns involved landowner opposition to land development, obliteration of existing trails, and losses of potential trail locations to land use changes. Lack of funding and concerns about trail conflicts and other issues related to multiple use were the next most pressing issues identified. Ability

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to provide trails close to where people live is also a serious issue for trail administrators. Across the South, State agencies can play a critical role in trail supply by conducting and maintaining an inventory of the number, length, and condition of trails so that trends and problems can be identified and addressed.

Supply on private land—Privately owned land dominates southern forests. Corporate private owners typically provide recreation access by leasing their land to clubs, counties, or others. Individual owners usually have little to none of their land open, either through lease or other means (Teasley and others 1999). The number of southern owners allowing the public to recreate on their land has been decreasing (Cordell and others 1999). It appears that less land will be open to public recreation in the future (table 11.3).

Without some intervention, then, it appears that the amount of private land available for public recreation will decline. There may be opportunities to change that trend, however. Many owners are highly interested in improving the natural conditions of their land. One motivation might be collaborative stewardship with interested potential users. Four of the nine fastest growing recreation activities involve viewing and learning. Partnerships seem possible between owners and those interested in having opportunities to see, study, and photograph wildlife, wildflowers, birds, and other natural attributes of forests. In exchange for such use, owners might be helped to achieve their goal of improving the natural conditions of their land. Planting food species for wildlife, improving and protecting habitat, and monitoring users and mitigating their impacts may open a vast opportunity for owners and interested users alike.

Public land will likely offer better opportunities for new supply, but only to a limited extent. Lack of fiscal resources, movement toward low-impact uses, and a greater emphasis on ecosystem health on Federal land will bring more attention to the issue of visitor capacity than in the past. Increasing attention also may have to be directed at avoiding conflicts among uses.

Table 11.3—Percent of owners indicating more, same, or less land open to recreation for nonfamily members by time period and region, 1995-96

Time period	South	Nation
	- - - - *Percent* - - - -	
Five years ago compared to now		
More	5.0	5.0
Same	86.1	88.2
Less	8.6	6.8
Five years hence compared to now		
More	4.2	3.0
Same	81.7	83.7
Less	14.1	13.3

Source: National Private Landowners Survey (NPLOS), Environmental Resource Assessment Group, Athens, GA.

Potential Conflicts Between Different Forms of Recreation

The sources of information on this subject were published articles and the experiences of the authors. These sources show that conflicts between different forms of recreation use have arisen with increasing frequency in recent years. The root cause for rising conflicts is simply the increase in demand for most outdoor recreation activities. Further complicating the effects of rising demand are changes in the way some activities are pursued. Technology-driven activities like off-road motorized vehicle driving, mountain biking, jet boating, hang gliding, and various forms of mechanical trail use are rising in popularity. Numbers of participants in activities like wildlife viewing, birdwatching, and nature photography also are growing very rapidly. The prospects for conflicts between nature watchers and people participating in technology-based activities are considerable. Land managers, therefore, are being forced to examine more closely the question of access and who gets what, when, and where. Early detection of user conflicts and effective conflict resolution depend on understanding where and how conflicts arise. Resolving a conflict in its initial stages before users ally themselves with larger, better organized interest groups helps to avoid costly political and legal actions.

At least two primary conceptual models help increase understanding of recreation conflict: the cognitive and the normative models. The cognitive model proposes that conflict occurs as a result of goal interference attributed to another's behavior (Gibbons and Ruddell 1995, Jacob and Schreyer 1980). Recreation goals are based on social (such as family affiliation), psychological (such as solitude), and physical (such as exercise) motives. When users with (1) high personal attachment to an activity, (2) high personal attachment to the resource, (3) specific and focused ways of experiencing the environment, and/or (4) low tolerance for other users encounter users with different beliefs and behaviors, there is ample potential for conflict (Jacob and Schreyer 1980).

The normative model assumes that conflict arises when users do not share the same norms or social values, independent of physical presence or actual contact between them (Vaske and others 1995, 2000). Norms are standards of acceptable and unacceptable behaviors for specific places. Examples are an acceptable number of rafters on a whitewater river or the appropriate level of human-induced noise at a campground. Unacceptable behavior may involve both users engaged in the same activity and users in different activities.

Of the two models of conflict, the cognitive approach has received more widespread acceptance. Studies support the role of at least one of the four factors of goal interference as influencing conflict (Gibbons and Ruddell 1995, Gramman and Ruddell 1989, Ivy and others 1992, Ramthun 1995). However, there is also support for the social values approach. Vaske and others (1995), for example, attribute conflict in hunting to differences in social values held by hunters and nonhunters.

Although most studies have been done in the parks and forests of the West, most of their findings can be generalized to the South. The bulk of these past studies suggests that recreation conflict is asymmetrical. That is, there is a tendency for one group (mostly traditional and nonmotorized users) to perceive more problems than the other group with whom they are in conflict. This other group, which typically holds an asymmetrical view of the level of conflict, is typically composed of nontraditional, mechanized, or motorized users. This finding of differential levels of perceived conflict holds for cross-country skiing versus snowmobiling in Minnesota (Knopp and Tyger 1973), for oar-powered versus motor-powered whitewater boating in the Grand Canyon (Shelby 1980), for anglers versus water-skiers on Midwest reservoirs (Gramman and Burdge 1981), for paddling canoeists versus motorboaters in the Boundary Waters canoe area (Adelman and others 1982), and for hikers versus mountain bikers in the Rattlesnake National Recreation Area (Watson and others 1991). Ramthun (1995) found that one-third of hikers on a trail near Salt Lake City, UT, sensed conflict with mountain bikers, while less than 6 percent of bikers perceived conflict. Gibbons and Ruddell (1995) found that helicopter skiers in the Wasatch National Forest in Utah reported no conflict, while nonmotorized back-country users reported high levels of conflict.

Two studies specific to the South help our understanding of recreation conflict. In a survey of winter visitors to Bird Island Basin in the Padre Island National Seashore in Texas, Ruddell and Gramman (1994) reported that noise-induced conflict (measured as sensitivity to loud radio playing) was a result of both goal interference and violation of norms. Visitors motivated by "being with people who were considerate of others" were more likely to perceive conflict than were visitors who were motivated by "being with friends and people like themselves." In the second southern study, Ivy and others (1992) found support for asymmetrical conflict. Canoeists perceived more conflict than motor-boaters in the backwater of the Everglades National Park in Florida.

Conflict resolution may involve both zoning and education. When the source of conflict is goal interference, it is more appropriate to consider zoning by time, space, or activity. Zoning can ensure that different types of users are physically separated. Zoning seems less effective when the conflict is attributable to differing social values, because such conflict does not necessarily require physical presence or actual contact between users. Off- and on-site education and information campaigns can highlight rules and regulations, as well as acceptable behaviors, for engaging in various recreation activities. An education campaign for a ballot initiative for spring black bear hunting in Colorado demonstrated that education can reduce the potential for conflict (Manfredo and others 1995).

Settings where conflict is likely to occur include trails, back country, developed sites, rivers, lakes, streams, and roads. For each of these settings, we used the NSRE participation trends data to examine activities likely to be in conflict because of growth in numbers of participants (table 11.1). We looked at both numbers of people reporting participation in 2000 and at percent growth in numbers from 1995 to 2000 for each setting. Since some activities may occur in more than one setting, some are listed for more than one setting.

■ **Trails—**The trail activities with the greatest numbers of participants include walking, bicycling, and hiking. Increasing numbers of people participating in these activities on limited trail resources is likely to result in rising conflicts with horse-back and off-road motor vehicle riders, who often use the same trails. Backpacking is a fast-rising trail activity, as is horseback riding. These two activities often can be in conflict. The rapid rise in number of day hikers, many of whom hike within the same large areas often used by backpackers, may result in greater perceived crowding by backpackers, who typically are seeking relative solitude.

■ **Back country—**Viewing and photographing wildlife, viewing and photographing birds, and day hiking are the most popular of activities that typically occur in back-country settings. For the most part, these are also among the fastest growing of outdoor activities. People who like to view and photograph nature often disapprove of hunting, so conflicts with hunters are likely. Hikers and viewers seeking solitude also are likely to perceive conflicts arising from motorized users.

■ **Developed sites—**A wide variety of activities occurs in or near devel-oped sites, such as campgrounds and picnic areas. Family gatherings out of doors, walking, visiting nature centers, and picnicking are among the most popular developed-site activities. At the same time, jet skiing is one of the fastest growing of outdoor activities, and it is often associated with developed sites. Noise and turbulence can cause conflicts with on-shore users of these developed sites. Conflicts involving developed sites, however, are likely to be fewer, and less contentious, than in many other settings because developed sites are designed to accommodate larger numbers and a wider variety of users at one time, and users expect to see other people.

■ **Streams and whitewater—**Water attracts a wide variety of visitors, including swimmers, viewers of fish, anglers, and users of muscle- and motor-powered water-craft. The possibilities of conflict are obvious. For the most part, all the uses just listed are incompatible with one another.

■ **Roads and their nearby environs—**Roads are the primary means of accessing forests for many forms of recreation. Future conflicts are most likely to be experienced through traffic problems, crowding of access areas, and incompatible uses.

From the standpoint of supply of recreation opportunities, one of the most difficult types of conflict is between users and owners of private tracts. These conflicts are a problem because they can lead to posting and a shrinking of supply. Most of the forested land in the South is privately owned, and most private forest tracts are owned by individuals and families. Results from the 1995 National Private Landowner Survey (Teasley and others 1999) tell of some of the possibilities for conflict.

About 59 percent of individual southern landowners have indicated that improving wildlife, water, aesthetics, and other natural compo-nents of their land are either a primary or secondary emphasis in their land management. Just over 7 percent emphasize making money from their land. Sometimes landowners encounter public use effects that can be incompatible with their land and conservation goals. The more prominent of these problems include dumping garbage, littering, illegal hunting and fishing, damage to fences and gates, damage to roads, disturbance of wildlife, and careless shooting. About 41 percent of owners in the South post their land. The most common reasons for posting are to know who is on the property, to keep people out who do not have permission, to keep people out that the owner does not know, and to avoid property damage. Of owners who post, 81 percent anticipate posting the same acreage in the future, but an additional 16 percent anticipate posting more land.

Increasing demands for off-road vehicle use, hunting, fishing, and other of the more consumptive recreation activities are likely to bring about more conflicts between recreation participants and landowners in the future. In part as a response, many of the higher income residents of the South are purchasing their own land for personal recreation pursuits. Land purchased for the owner's personal recreation is less likely to be open to others for recreation. Conflicts are likely to continue to grow as a result of rising demands for access to private land, even though the owners have no obligation to provide public access.

Potential Adverse Impacts of Recreation Activities on Forested and Aquatic Ecosystems and Where They Are Located

Depending on the type and intensity of recreation use, the type and fragility of a forest site, and the type and level of site management, recreation in forested ecosystems impacts soil, water, vegetation, and animal life. To our knowledge, there is no comprehensive regionwide assessment of the impacts of recreation on forests. Such an undertaking would be enormously complicated and costly. There are only a few isolated studies of impacts, and these are primarily limited to trails, rivers, and campgrounds on public land. The most comprehensive treatment of recreation use found dealt with wildlife (Knight and Gutzwiller 1995). Nevertheless, recreation can significantly affect natural systems, such as forests, in the following ways:

■ **Soils**—Repeated foot, horse, motor vehicle, or other recreation traffic can compact many types of soil, especially those with high clay content as is prominent in the Piedmont and mountain areas of the South. A heavy volume of traffic also can loosen topsoil and reduce vegetative cover, inviting erosion. Further, chemicals used in site management or by recreationists can change the chemical properties of soil.

■ **Water**—Surface water in streams and in impoundments, groundwater, and runoff from precipitation are all potentially impacted by recreation use and management. Chemicals, such as herbicides, used on or near shorelines or used directly in water to control aquatic vegetation will almost certainly alter the chemical and biological properties of water. Humans coming into contact with water can introduce high levels of bacteria. Recreation near or along shorelines also disturbs soils, diminishes the density and health of vegetation, and reduces populations of animals, especially amphibians and waterfowl. Heavy recreation traffic often causes high levels of sedimentation. Heavy traffic also can disrupt fish life patterns, including spawning. Overfishing interrupts balances among vertebrate and invertebrate species, both aquatic and terrestrial.

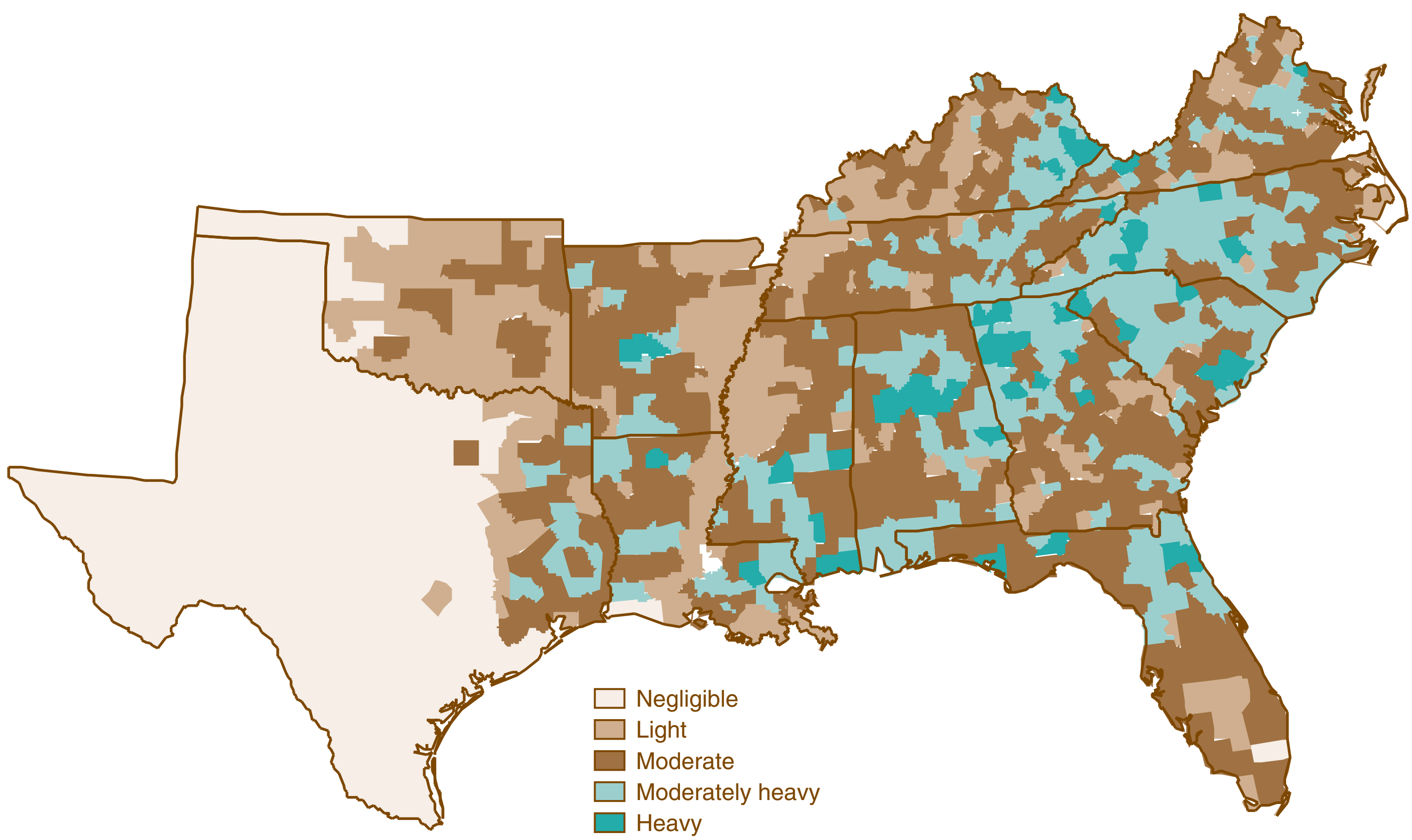

Figure 11.1—Hotspots of recreation demand pressure on forests, Southern States, 2000.

■ **Vegetation**—Grasses, herbs, shrubs, trees, and aquatic vegetation all can be impacted by outdoor recreation. Recreation in developed sites mainly impacts the planted grasses, residual trees left for shade, and immediately surrounding woodlands. From a broad perspective, these impacts are relatively minor. There is also vegetative impact on and near trails caused by hiking, horseback riding, mountain biking, and motor vehicles. Crushing ground vegetation, breaking reachable herbal and woody vegetation, and exposure and damage to roots are the forms of damage usually encountered. Along roads, ground vegetation can be heavily impacted in unhardened areas by motor vehicles, and nearby sensitive plants can be impacted by exhaust emissions. Typically, vegetation along roads is not much impacted. Aquatic vegetation and vegetation along shorelines can be impacted by water disturbance and by wave action caused by boats. Persistent erosion and undercutting of shorelines is typical of Piedmont and mountain lakes. Native vegetation on a wide variety of settings can be cumulatively impacted by competition from exotic species planted or otherwise introduced as a part of recreation site management.

■ **Animal life**—Terrestrial mammals, birds, insects, bacteria, subterranean animals, fish, and all other forms of animal life can be dramatically impacted by recreation use. The presence of recreation users influences animal behavior and animal habitat. Hunting of game animals alters their natural age and sex ratios. Horses and all-terrain vehicles have high potential for altering wildlife habitat. We will not attempt to list all the possible adverse effects of recreation on ecosystems. The main point is that recreation effects on the land are not benign. Ever-increasing use of forests and other natural systems will have increasing impacts (Knight and Gutzwiller 1995).

In figure 11.1, percentage of area in forest cover in southern counties is cross-indexed with outdoor recreation participation per 1,000 population based on data from the NSRE in 1995 (Cordell and others 1996, 1999). Recreation travel data indicate that the majority of outdoor recreation participation occurs within 50 miles of people's residences, a distance approximately the same as the distance from the center of one county to the outer boundary of an adjacent county in the South (Cordell and others 1999). We have indexed reported participation from residence relative to percentage of resident and adjacent counties' area in forest cover to identify counties with a high probability of heavy recreation pressure. In such counties, the level of forest cover and recreation participation are both high. The mapped index highlights counties where heavy recreation pressures on forest resources are anticipated. Counties with these conditions are identified as hotspots. Where there is little to no forest cover (for example, in an urbanized county) or little to no recreation demand, negligible pressures are likely occurring. Our focus is on counties with relatively abundant forest resources where moderately heavy to heavy recreation pressures are occurring. These counties we identify as hotspots, and mostly they are found in:

■ South coastal North Carolina and coastal South Carolina, especially in the Charleston area;

■ North coastal Florida, the Jacksonville area;

■ Gulf coastal north Florida; coastal Alabama, Mississippi, and Louisiana, especially the New Orleans Delta area;

■ The "Piedmont Crescent" running from north-central North Carolina to the Birmingham area in Alabama;

■ South-central Mississippi, especially the Jackson area;

■ The Ozark and Ouachita Mountains and the Little Rock, AR, area; and

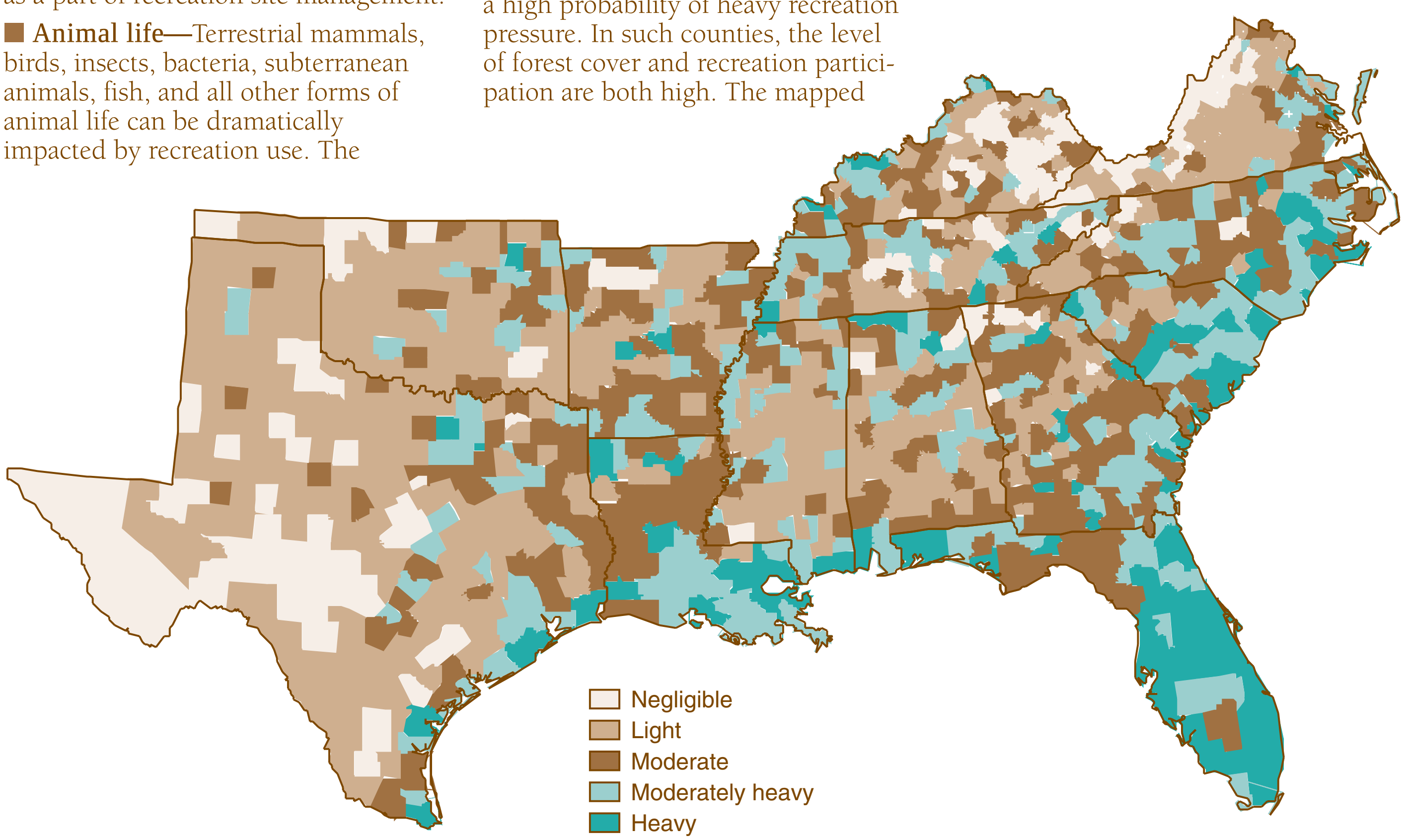

Figure 11.2—Hotspots of recreation demand pressure on water and wetlands, Southern States, 2000.

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- Northeastern West Virginia and western Virginia.

To address recreation pressures on aquatic systems, we use data from the National Resources Inventory (NRI) describing the acres of water bodies and wetlands. The NRI is conducted every 5 years by the Natural Resources Conservation Service. Figure 11.2 shows a number of areas with relatively abundant water and wetlands that also have heavy recreation pressures. The same approach of using data from resident and adjacent counties as explained above was used to identify counties with water and wetland resources under recreation pressure. Pressures on water bodies often are high because water is a very prominent draw for outdoor recreation. Counties that are hotspots and those with moderately heavy pressures include most of the coastline of the South from Virginia to Texas. Almost all of the Florida peninsula is coded as a water and wetland hotspot. Other areas include:

- Piedmont South Carolina;
- Northern Alabama;
- Northern Louisiana;
- Central Arkansas, especially the Little Rock area; and
- Isolated clusters of counties in east Texas, northeastern Oklahoma, western West Virginia, central Georgia, and western Tennessee.

Discussion and Conclusions

Forest recreation in the South has been growing steadily. Growth in demand for viewing and photographing nature has been particularly rapid. Also growing in popularity is the gathering of various NTFPs such as berries, mushrooms, and herbs. Nonmotorized boating also is becoming more popular. These are among the fastest rising activities in the region, adding the most participants year by year of all activities. Also growing are hiking, backpacking, bicycling, horseback riding, coldwater fishing, walking, and visiting nature centers. Camping and off-road driving also are growing, at rates much faster than the population of the South. Slower growing activities include motorboating, sightseeing, hunting, and waterskiing. Across the Nation, as well as the South, viewing, learning, and photography activities have usually topped the list of activities adding large numbers of participants. There is no end in sight to the growth in demand and the pressures it will place on the forests of the South.

Given the dominance of private land in the region, it would seem that the preponderance of these growing demand pressures could be met by private ownerships. Among individual owners, however, approximately 59 percent indicate that an emphasis in managing their land is maintaining and improving the lands' natural components. For 37 percent of owners, improving the natural components is the primary thing they emphasize. Accordingly, only about 14 percent of owners in the South permit the outside public to use their land, even though the greatest growth in demand is for nature appreciation and photography. Unless conditions become more favorable for landowners, the percentage of them permitting public access is likely to continue to decrease, as it has been doing for several years. Increasing demands for off-road vehicle use, hunting, fishing, and other of the more consumptive recreational activities may bring about even more private land closure. Many individuals and families are purchasing land for their own personal recreational pursuits. These owners are even less likely to open their land to others for recreational pursuits. Thus, the weight of providing for increases in public recreation demand in the future is likely to fall mostly on public providers,who increasingly face significant budget and capacity constraints.

The percentage of private owners in the South who permit the outside public to use their land is likely to decrease even further, unless conditions for owners change appreciably. In that four of the nine activities adding the most participants are oriented toward viewing and learning, increasing numbers of partnerships between owners and potential users seem possible. These potential partners may represent for owners a better strategy for achieving their goal of improving the natural conditions on their land, while at the same time accommodating greater recreation use. Planting food species, improving and protecting habitat, monitoring users and mitigating their impacts may open a vast, untapped opportunity.

Public land will likely offer better immediate opportunities for new supply, but only to a limited extent. Lack of fiscal resources, movement toward low-impact use policies, and a greater emphasis on ecosystem health on Federal land focuses more attention on visitor capacity than it has in the past. This increased attention is especially true for activities frequently in conflict with other uses and for those that most impact natural conditions. As with private land, increasing interest in viewing and learning activities could represent an important way for land management agencies to get tasks done that are necessary for improving and maintaining these natural conditions.

Increasing recreational use of forests is not without its drawbacks. In a number of forested areas in the South, recreation participation is likely to place greatly increased pressures on forest resources, public and private. If we are to sustainably manage our southern forests, these areas, which we have identified as hotspots, must be closely monitored. If left to develop as pressures demand, long-term health and productivity of many of our southern forest areas may be seriously impaired. Where pressures are predicted to occur (or are occurring), collective, multiscale planning and actions are needed. The forestry community is in a unique position to act as a leader in such planning and collaborative conservation efforts. Being situated across all levels of government and in the private sector, forestry professionals, including scientists, can act as catalysts to action.

Efforts to sustain forest productivity and health must include not only timber and recreation; increasingly, they must also include NTFPs of a wide variety. Both animals and plants are increasingly sought for increasingly diverse personal and commercial uses. Typically, NTFPs introduce nontraditional users, many of whom have little knowledge of the makeup of healthy forest ecosystems. Looking for leaves, twigs, vines, ferns, cones, fruits, bark, foliage, sap, firewood, poles, and boughs, these gatherers can have very significant impacts by interrupting balances among species and their habitats. Removal of edibles such as walnuts, hickory nuts, ramps, wild blueberries, blackberries, elderberries, persimmons, and a wide variety of other materials reduces food supplies for wild species. While there is little hard data on the gathering of these and other forest products, it is clear that gathering is increasing and must become a more prominent component of forest planning.

In conclusion, recreation, aesthetic, forest product, and a wide variety of other demands are increasingly being placed on the South's forests. While the profession of forestry often focuses much of its time and talent on stand inventories, game habitat, water production, forest health, and commodity interests, these rising nontraditional, aesthetic demands are beginning to assume a dominance over traditional forest resource demands. Greater research and monitoring attention is immediately needed to better understand the nature of these demands and their potential unfettered consequences.

Literature Cited

Adelman, B.J.; Heberlein, T.A.; Bonnicksen, T.M. 1982. Social psychological explanations for the persistence of a conflict between paddling canoeists and motorcraft users in the Boundary Waters Canoe Area. Leisure Sciences. 5: 45-62.

Betz, Carter J.; English, Donald B.K.; Cordell, H. Ken. 1999. Outdoor recreation resources. In: Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 39-182.

Blumenthal, Mark; Busse, Werner R.; Goldberg, Alicia [and others]. 1998. The complete German Commission E monographs: therapeutic guide to herbal medicines. Boston: American Botanical Council. [Number of pages unknown].

Chamberlain, J.; Bush, R.; Hammett, A.L. 1998. Non-timber forest products: The other forest products. Forest Products Journal. 48(10): 10-19.

Cordell, H.K.; McDonald, B.L.; Lewis, Burt [and others]. 1996. United States. In: World leisure participation: free time in the global village. Wallingford, UK: CAB International: 215-235.

Cordell, H. Ken. [In press]. Outdoor recreation 2000. State College, PA: Venture Publishing, Inc.

Cordell, H. Ken. 1999. Framework for the assessment. In: Outdoor recreation in American life : a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 31-38.

Cordell, H. Ken; Betz, Carter J.; Bowker, J.M. [and others]. 1999. Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing. 449 p.

Eisenberg, David M.; Davis, Roger, B.; Ettner, Susan, L. [and others]. 1998. Trends in alternative medicine use in the United States, 1990-1997: results of a follow-up national survey. Journal of American Medical Association. 280(18): 1569-1575.

Fischer, David, W.; Bessette, Alan E. 1992. Edible wild mushroom of North America. Austin, TX: University of Texas Press. [Number of pages unknown].

Gibbons, S.; Ruddell, E.J. 1995. The effect of goal orientation and place dependence on select goal interferences among winter backcountry users. Leisure Sciences. 17: 171-184.

Grafton, William N. 2000. Forest provides income from crafts, edibles and more. West Virginia Farm Bureau News. [Place of publication unknown]: West Virginia University Extension Service. February. [Number of pages unknown].

Gramman, J.H.; Burdge, R. 1981. The effect of recreational goals on conflict perceptions: an evaluation and synthesis of research. Journal of Leisure Research. 13: 15-27.

Gramman, J.H.; Ruddell, E.J. 1989. Characteristics, management preferences, and conflict perceptions of Bird Island Basin visitors, Padre Island National Seashore. Tech. Rep. 14. [Place of publication unknown]: [Publisher unknown]. [Number of pages unknown]. Contract report to the National Park Service, Southwest Region.

Hesler, L.R. 1960. Mushrooms of the Great Smokies. Knoxville, TN: University of Tennessee Press. [Number of pages unknown].

Ivy, M.I.; Stewart, W.P.; Lue, C. 1992. Exploring the role of tolerance in recreational conflict. Journal of Leisure Research. 24: 348-360.

Jacob, G.R.; Schreyer, R. 1980. Conflict in outdoor recreation: a theoretical perspective. Journal of Leisure Research. 12: 368-380.

Knight, Richard L.; Gutzwiller, Kevin J. 1995. Wildlife and recreationists: coexistence through management and research. Washington, DC: Island Press. 372 p.

Knopp, T.; Tyger, J. 1973. A study of conflict in recreational land use: snowmobiling versus ski-touring. Journal of Leisure Research. 5: 6-17.

Kronrad, Gary. 2000. NTFP landowners can profit from a carbon credit market. [Washington ,DC]: [Society of American Foresters]. [Number of pages unknown].

Landrum, Ney C. 1999. America's State parks–an end-of-century assessment. In: Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 112-115.

Levi, Michael. 1995. Growing shiitake. Woodland Owner Note 20. Raleigh, NC: North Carolina Cooperative Extension Service. [Number of pages unknown].

Manfredo, M.J.; Vaske, J.J.; Decker, D.J. 1995. Human dimensions of wildlife management: basic concepts. In: Wildlife and recreationists: coexistence through management and research. Washington, DC: Island Press: 17-31.

Metzler, Susan; Metzler, Van. 1992. Texas mushrooms: a field guide. Austin, TX: University of Texas Press. [Number of pages unknown].

Miller, Orson, K., Jr. 1979. Mushrooms of North America. New York: Dutton. [Number of pages unknown].

Moore, R.L. 1994. State trail programs: a survey of State trail administrators. Denver: National Association of State Trail Administrators. [Number of pages unknown].

Ramthun, R. 1995. Factors in user group conflict between hikers and mountain bikers. Leisure Sciences. 17: 159-170.

Ruddell, E.J.; Gramman, J.H. 1994. Goal orientation, norms, and noise-induced conflict among recreation area users. Leisure Sciences. 16: 93-104.

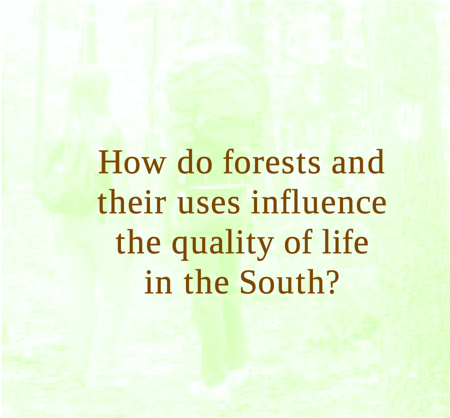
Shelby, B. 1980. Contrasting recreational experiences: motors and oars in the Grand Canyon. Journal of Soil and Water Conservation. 35: 129-131.

Teasley, R. Jeff; Bergstrom, John C.; Cordell, H. Ken [and others]. 1999. Private lands and outdoor recreation in the United States. In: Outdoor recreation in American life: a national assessment of demand and supply trends. Champaign, IL: Sagamore Publishing: 183-218.

Vaske, J.J.; Carothers, P.; Donnelly, M.P.; Baird, B. 2000. Recreation conflict among skiers and snowboarders. Leisure Sciences. 22: 297-314.

Vaske, J.J.; Donelly, M.P.; Wittmann, K.; Laidlaw, S. 1995. Interpersonal versus social-values conflict. Leisure Sciences. 17: 205-222.

Watson, A.E.; Williams, D.R.; Daigle, J.J. 1991. Sources of conflict between hikers and mountain bikers in the Rattlesnake NRA. Journal of Park and Recreation Administration. 9: 59-71.



Chapter 12: Forests and the Quality of Life

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Key Findings

- Indicators of economic conditions were negatively correlated with areas of concentrated employment in the forest products industry. Industrial concentration in the pulp and paper sector and the primary wood products sector was negatively correlated with median household income and the proportion of the population completing high school and positively correlated with unemployment and poverty rates. Further, industrial concentration in these sectors was negatively correlated with population growth and other indicators of economic development such as concentrated employment in the finance, insurance, and real estate sector. The degree to which the pulp and paper sector and the primary wood products sector influenced prevalent economic conditions cannot be easily determined.

- The forest products industry provided good paying jobs relative to other economic sectors in areas where the forest products industry was located. On average, income per job in this industry ranged from marginally higher (in the primary and secondary wood products sectors) to much higher (in the pulp and paper sector) than average income per job for typical sources of employment.

- Indicators of social conditions were mixed with respect to employment in the forest products industry. For example, industrial concentration in this industry was positively correlated with the proportion of owner-occupied housing and the proportion of the population that voted in presidential elections and was negatively correlated with rates of crime and divorce. However, industrial concentration was negatively correlated with the percent of the population graduating from high school and, in the case of the primary wood products sector, was positively correlated with infant mortality rates. The degree to which the forest products industryinfluenced prevalent social conditions cannot be easily determined.

- Through the export of wood products to other regions, the forest products industry contributed to local economies by bringing in income, which then circulated through economies via the purchase of locally provided goods and services. The forest products industry also contributed to the local tax base of communities via income and property taxes.

- Forest amenities were impacted in areas with concentrated employment in the pulp and paper sector and the primary wood products sector. Concentrated employment in these sectors was correlated with various indicators of an increasingly industrialized forest, including higher concentrations of plantation acreage, younger pine forests, and greater timber harvest intensity in hardwood forests.

- The forest related recreation and tourism sector was concentrated in areas with more natural forest conditions. Increasing concentration of employment in this sector was correlated with higher proportions of upland hardwood forests, older forests, and forests where harvest pressure was less intense.

- Areas of concentrated employment in the forest related recreation and tourism sector were correlated with better economic conditions and relatively higher levels of economic development. An increase in the degree of concentration in this sector was correlated with an increase in median household income; an increase in the rate of high school graduation; a decline in unemployment and poverty rates; an increase in employment concentration in the finance, insurance, and real estate sector; an increase in employment in the retail and wholesale sectors; and an increase in the rate of population growth. However, increased concentration in this industry was also correlated with an increase in the crime rate. Thus, areas of concentrated employment in the forest related recreation and tourism sector face different economic development challenges than do areas of concentrated employment in the wood fiber-based forestry sectors.

- Competing demands on southern forests will likely increase as timber production intensifies in the South due to the region's competitive advantage in timber growing and as people continue to move to locations in the South that provide natural forest amenities. In some areas these trends will intensify the social, political, and ideological tension related to forest use. And in some areas, quality of life for residents may decline where forests with natural amenity values come under increased pressure for timber harvest and intensified forest management.

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Introduction

Quality of life is a multidimensional concept that is similar to and often used interchangeably with the terms "well-being," "welfare," and "standard of living." The term "quality of life" refers to a summary measure of well-being, where the locus of well-being is the individual members of society. This frame of reference presents analysts with substantive difficulties, because there is no generally accepted theoretical model to guide analyses. The lack of a theory of what constitutes "the good life" derives from the fact that the way in which people identify and integrate the important domains of their lives are generally unknown (Mukherjee 1989, Wish 1986). Quality-of-life indicators are typically chosen based on intuition (Bayless and Bayless 1982, Diener 1995) and ease of data collection (Power 1980). Further, the means by which the well-being of individuals can be meaningfully aggregated to represent social welfare is not a simple matter (e.g., see Arrow 1983), and how well off one is in society relative to others may be more important than any absolute measure (Easterlin 1974).

To provide the reader with a better sense of how the quality-of-life concept has been treated in major studies, we briefly review some well-known indices. This leads us to a consideration of how forests contribute to the quality of life in the South.

Well-Known Indices of the Quality of Life

One of the most widely known indicators of the quality of life is the Human Development Index of the United Nations Development Program (United Nations Development Program 1998). The Human Development Index combines national indicators of income, life expectancy, and education into a single number. [This is accomplished by: (1) computing a standard score for each component indicator by country (where the standard score measures the difference between a country value and the maximum value divided by the range of values across countries), and (2) summing the standard component scores for each country.] This procedure results in a measure that allows countries to be ranked by the summary index and allows comparisons to be made across countries regarding quality of life.

Within the United States, there is concern among social scientists that "more" does not unambiguously imply "better," that social costs may increase along with economic growth, and that economic measures alone provide a biased estimate of how well the people of the United States are doing. A number of indicators of social progress have been developed that adjust standard economic measures to account for social and environmental conditions. One such model is the Genuine Progress Indicator that includes measures of such things as personal consumption, income distribution, value of housework and parenting, cost of crime, loss of old-growth forests, and loss of leisure time (Cobb and others 1995a, 1995b). Values for the component indicators are summed up to produce a summary measure that is tracked over time to indicate trends.

Within the private sector, use of the quality-of-life concept is evidenced by the popularity of rankings of the best places to live, work, or do business based on multidimensional scales of well-being (e.g., see Boyer and Savageau 1981, Garoogian and others 1998, Morgan Quinto Corporation 1998). These indices use arbitrary methods for selecting and combining component indicators for wide-ranging measures of quality of life such as income, pollution, taxes, quality of public schools, and number of women-owned businesses.

Thus, we can see that summary measures of the quality of life are used to make comparisons, either across different places at a given point in time or over time for given locations (Dasgupta 1999). These data allow analysts to evaluate trends, anticipate future conditions of social well-being, and determine how well certain locations are doing relative to other places. However, significant methodological issues remain regarding how to select component measures and the appropriate weights to be placed on components in creating a summary index. In this chapter, we attempt to bypass some of these methodological problems by using an array of indicators that are not meant to be additive but rather provide a pluralistic view of the elements which enter into an assessment of forests and quality of life. [This disaggregate approach, focusing attention on a set of component indicators, is also used in assessments of the social health of the Nation (e.g., see Miringoff and Miringoff 1999).]

Forest Related Indicators

In this chapter, we present three classes of indicators related to forests and the quality of life: (1) economic, (2) social and demographic, and (3) forest amenities. The rationale for including each class follows.

Economic indicators—Recent studies have shown that income is highly correlated with various indices of the quality of life (Dasgupta 1999, Diener 1995, Ferriss 2000). Although correlation does not imply causation, these results suggest that economic variables are useful in providing measures of well-being and should be included in quality-of-life analyses.

From a forestry perspective, forests provide jobs and income to people who grow, harvest, and process timber as well as other nontimber forest products such as pine straw, wild edibles, and medicines. Forests also provide natural settings for outdoor recreation. Whether providing inputs to the forest products or recreation industries, forests contribute to quality of life by providing income and employment, particularly in rural areas where other economic opportunities may be limited.

Some people have argued that the contribution of the productive aspect of forests to quality of life is greater than simply the jobs created in the forest products sector. This argument maintains that the forest products industry is an important engine for economic growth in forested regions (e.g., see Schallau 1994). This view is formalized with the economic base model which argues that through the export of goods and services, basic industries bring in money from outside of the local economy, which stimulates job creation in the local sector through spending patterns on local goods and services. The forest products industry also contributes to the local tax base of communities via income and property taxes.

Does the export of timber products outside of local economies enhance the quality of life for other participants in the local economy? Although this question is not easily answered, it is useful to consider some of the limitations of the economic base model that have been articulated by forest policy analysts (Crone and others 1999, Niemi and Whitelaw 1999, Power 1996). It has been argued that if basic industries have a detrimental impact on the local environment, this would decrease the well-being of people who live there. Because impacts of industry on the natural environment are not included in economic base calculations, failure to account for such impacts imparts a bias to quality-of-life assessments. In addition, the economic base model focuses attention on the export of goods and services outside a region, but does not consider the flow of money generated by people who are attracted to an area because of its natural amenities (English and Bergstrom 1994). This omission includes people who visit an area for recreation and tourism purposes as well as people who decide to move to an area because of the quality of the natural amenities found there.

Social and demographic indicators—Social indicator research has been applied to issues related to rural development (e.g., see Richmond and others 2000) and forest-dependent communities (e.g., see Parkins 1999). A widely cited study conducted in the Northeast United States concluded that "Forest communities are among the least prosperous of all rural communities; standards of health and happiness tend to be lower than average; while family status is high, divorce rates are very high, housing and public services and amenities are poor; economic stability is low, with high seasonal unemployment, high rates of population turnover and poor wages and earnings" (Drielsma, J.H. 1984. The influence of forest-based industries on rural communities. Unpublished Ph.D. dissertation. On file with: Yale University, New Haven, CT). While conditions in northeastern forest communities cannot be used to characterize forest related communities in the South, this conclusion motivates the need for a regional assessment of social and demographic variables.

In the United States, recent empirical studies provided evidence that rapid rural population growth has not resulted from growth of extractive industries or manufacturing but rather has resulted from the attractiveness of natural environments (Deller and others 2001, English and others 2000). Johnson and Beale (1994) found that during the early 1990s, the fastest growing counties in the United States were nonmetropolitan counties that were destinations for retirement-age migrants or were recreation centers. Of the 285 counties identified as recreational, 47 (16 percent) are located in the South (Beale and Johnson 1998). Although some of these southern counties are attracting in-migrants because of their proximity to the coast, many southern recreational counties experiencing rapid growth are found in forested areas such as the Southern Appalachian Mountains and the Ozark-Ouachita Highlands.

Forest amenity indicators—Forests provide a broad array of amenity services. Amenity values are usually thought to derive from the visual qualities of landscapes, although they may also arise from appreciation for ecosystem integrity and health (Gobster 1999). Because appreciation of forest amenities is subjective, the measurement of amenity value is difficult. However, natural resource and environmental economists have developed and formalized the view that the natural World provides benefits to members of society that are not accounted for in markets, and that people are willing to pay for enhancements in the quality of natural environments (e.g., see Freeman 1993, Krutilla and Fisher 1985). The theory and measurement of nonmarket values provides a useful perspective for understanding linkages between forest amenities and the quality of life.

The theory of nonmarket valuation and willingness to pay is based on a concept referred to as "consumer surplus," or the value of something above and beyond what is actually paid for it. Applied to the natural World, this concept can be represented by the metaphor "real income": "When the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (Krutilla 1967, p. 779). In a footnote to this remark, Krutilla goes on to state that "These would be the spiritual descendants of John Muir, the present members of the Sierra Club, the Wilderness Society, National Wildlife Federation, Audubon Society and others to whom the loss of a species or the disfigurement of a scenic area causes acute distress and a sense of genuine relative impoverishment." Using a somewhat different metaphor, Niemi and Whitelaw (1999) compare consumer surplus to a second paycheck that people receive as a bonus resulting from a high-quality natural environment. In a similar fashion, Power (1996) equates local economic well-being with the sum of money income (adjusted for the local cost of living) and the value of noncommercial environmental qualities.

In an attempt to analyze and quantify real income derived from natural environments, economists divide amenity values into the sum of use value and non-use value. In a forestry context, use value refers to the set of values derived from the direct use of forest environments for activities such as timber harvesting, recreation, hunting, fishing, wildlife viewing, and wild food collection. Non-use values are values not associated with current use and include such non-uses as maintaining the option to personally use part of the natural environment in the future (option value), leaving part of the natural environment for others to use in the future (bequest value), and the knowledge that part of the natural environment will continue to exist even if the individual holding this value never contemplates using it (existence value) (Krutilla 1967).

One of the major nonmarket benefits provided by forests is opportunities for outdoor recreation and leisure (e.g., see Cordell and Bergstrom 1999; Driver and others 1991, 1996). Recreation, wildlife, and fishing activities provided the major sources of benefits from national forests in the South (Pearse and Holmes 1993). In addition, recent studies concluded that non-use values of forest ecosystems are important sources of value to society as well (Haefele and others 1991, Holmes and Kramer 1996, Kramer and others 2002, Walsh and others 1990).

Nonmarket forest valuation studies have concluded that social welfare is

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greatest when forest protection and forest use are balanced (Boyle and Teisl 1999, Boyle and others 2001, Garrod and Willis 1997). However, the public has demonstrated concern with specific timber harvesting practices, especially clearcutting. For example, in a recent study of timber harvesting preferences of Maine residents, it was found that harvest prescriptions that left 153 or 459 trees live trees per acre were significantly preferred to prescriptions that left no trees remaining after harvest (Boyle and Teisl 1999, Boyle and others 2001, Holmes and Boyle 2002). This research finding is in concert with the announcement made by the Chief of the USDA Forest Service in 1992 that the Agency would drastically reduce the area subject to clearcutting in national forests (Backiel and Gorte 1992).

Public concern over clearcutting as a timber harvest and/or regeneration method presages the potential for ideological tension in the South between people holding those concerns and people who grow, harvest, and process timber and timber products (e.g., see American Forest & Paper Association 1994, Devall 1993). We see no a priori reason that public concern with clearcutting on public forests will not manifest as concern over even-aged management practices on private forests. Because private forests produce public goods in terms of benefits such as clean water, wildlife habitat, and scenic views, the perceived impairment or loss of such benefits will cause a loss of real income to people who value those forest amenities.

Methods

Defining "Forest Dependence"

One of the concerns brought forward by the public was a better understanding of the linkage between "forest dependency" and various indicators of the quality of life. In general, the concept of forest dependency is focused on the degree of concentration of a particular industry in a particular area.

Given this framework, analysts often proceed to a determination of dependent communities by identifying communities that exceed a given, arbitrarily imposed, dependency threshold. For example, in a recent study of rural areas in the United States, farming-dependent counties were defined as counties that had 20 percent or more of labor and proprietor income derived from farming (Cook and Mizer 1994). In another study, recreation dependence was defined as having at least 10 percent of total employment in eating and drinking establishments, hotels and other lodging, and amusement parks (Ross and Green 1985).

Linking Forest Dependence with Other Indicators

For the purposes of this chapter, we treat forest dependence as a continuous variable and focus attention on job (rather than wage) dependency. This perspective allows us to examine how variation in the level of concentration of forest related employment relates to variation in quality-of-life indicators. This is accomplished using Pearson's correlation coefficient (e.g., see Kalbfleisch 1985). In so doing, we stress that correlation does not imply causation, but rather indicates whether an increase in some variable is associated with an increase or decrease in another variable, or if two variables are independent. Further, this method allows us to determine the strength of the relationship between two variables. The correlation coefficient is constrained to fall between 1 and –1, and the closer the coefficient is to 1 in either direction, the stronger the linear relationship. Finally, the statistical analysis allows us to determine whether or not correlations are statistically significant (that is, statistically different than zero).

To evaluate linkages between industrial concentration (forest dependence) and various quality-of-life indicators, relevant comparisons can only be made between areas where specific industries are located. Thus, we exclude areas that do not support particular forest related industries from the correlation analysis.

Correlation analysis provides insight into cross-sectional trends in indicator variables within specific forest related industries. This approach is preferred to a simple comparison of indicator variables across forest sectors, because a confounding factor across sectors is population density. That is, differences in indicator variables across sectors may simply reflect differences in population density.

Forest Related Sectors

We focus attention on four forest related sectors that we subsequently refer to as the primary wood products sector, the secondary wood products sector, the pulp and paper sector, and the forest related recreation and tourism sector. The primary wood products sector comprises the following subsectors: (1) forest products (stumpage, pulpwood, fuel wood, Christmas trees, and fence posts), (2) logging camps and logging contractors, (3) sawmills and planing mills, (4) hardwood dimension and flooring mills, (5) special products, and (6) veneer and plywood. The secondary wood products sector comprises the following subsectors: (1) millwork, (2) wood kitchen cabinets, (3) structural wood members, (4) wood containers, (5) wood pallets and skids, (6) prefabricated wood buildings, (7) wood preserving, (8) reconstituted wood products, (9) wood products not included elsewhere, (10) wood household furniture, (11) wood TV and radio cabinets, (12) household furniture not included elsewhere, (13) wood office furniture, (14) wood partitions and fixtures, (15) furniture and fixtures not included elsewhere, (16) paperboard containers and boxes, (17) paper coating and laminated packaging, (18) coated and laminated paper not included elsewhere, (19) paper bags, (20) die-cut paper and board, (21) sanitary paper products, (22) envelopes, and (23) stationery products. The pulp and paper sector comprises the following subsectors: (1) pulp mills, (2) paper mills except those producing building paper, and (3) paperboard mills.

The forest related recreation and tourism sector is more difficult to define than the other forest related sectors. This is because the attribution of recreation and tourism activities to use of the forest is not straightforward, and data that might directly link recreation and tourism to forest-based activities are not available. Prior studies that attempted to identify recreation-dependent areas used arbitrary dependence thresholds (Ross and Green 1985) or more sophisticated criteria (Beale and Johnson 1998). One study demonstrated a statistical linkage between a number of variables, including public and private forest land and export employment in tourism-related sectors (English and others 2000). However, none of these studies provides a means of identifying specific areas in the South that have forest related recreation and tourism employment. Consequently, it was necessary to construct data that were consistent with this objective.

For the purposes of this chapter, the recreation and tourism sector comprises the following subsectors: (1) hotels and lodging, (2) eating and drinking establishments, (3) amusement and recreational services not included elsewhere, and (4) sporting and athletic goods not included elsewhere. A linkage between forests and recreation and tourism activity was then specified by imposing the criterion that forest land, as a percent of total land area, must equal or exceed the average for the South (58 percent). This rationale was used because areas meeting this criterion had greater-than-average land use in forests. A second criterion was included to exclude metropolitan areas from the forest related recreation sector. Imposition of these two criteria effectively excluded areas such as Disney World, Myrtle Beach, metropolitan areas, and developed areas along interstate highways from the analysis of forest related recreation and tourism.

Linking Forest Dependence and Economic Structure

A second concern brought forward by the public was to develop a better understanding of the linkages between different uses of the forest and economic structure. To maintain consistency with our focus on industrial concentration, we examined the correlation between forest dependency (industrial concentration in the four forest related sectors described earlier) and industrial concentration (the ratio of employment in each industrial sector to total employment in an area) in the following sectors: (1) agriculture; (2) mining; (3) construction; (4) manufacturing; (5) trade; (6) wholesale; (7) retail; (8) finance, insurance, and real estate; and (9) service and government. Again, it is important to emphasize that correlation (estimated using the Pearson correlation coefficient) does not imply causation. However, correlation analysis does allow patterns to be observed linking the degree of industrial concentration in forest related sectors and other industrial sectors. A description of such patterns provides preliminary evidence for future research that may seek to develop cause-and-effect relationships describing economic structure. However, the development of cause-and-effect relationships is beyond the scope of this chapter.

Specific Indicators Used in the Analysis

Income per job—Specific quality-of-life indicators were selected based on consideration of the issues discussed in the Introduction. To provide an indication of the economic benefit received by people working in forest related industries, total income per sector was divided by the number of jobs per sector for the four forest related sectors described earlier. These measures are not wage rates but represent average income per job. Income per job may be low because wage rates are low or because the typical job is only part time. Income per job was also computed for all jobs in the areas where the forest related sectors were located. This allowed a comparison to be made between average income per job in the forest related sectors and the typical job in those areas.

Economic, social, and demographic indicators—To evaluate quality-of-life indicators in areas with forest related employment, a subset of social, demographic, and economic variables were selected from two recent quality-of-life studies (Diener 1995, Ferriss 2000). From the socioeconomic and demographic indicators used in those studies, the following indicators were selected: (1) infant mortality rate, (2) violent crime rate, (3) median household income, (4) unemployment rate, (5) poverty rate, and (6) percent graduating high school.

Evidence in the literature that rural population growth is influenced by the supply of natural amenities caused us to include a measure of population growth in the analysis. Inclusion of a variable measuring the percent change in population allowed us to evaluate the relationship between the degree of industrial concentration in forest related industries and population dynamics.

Social cohesion is a concern in considering quality of life. The following indicators of social cohesion and the potential for collective social action used in other quality-of-life studies (Drielsma 1984; Hamilton 1993, 1999; Wish 1986) were included: (1) percent of owner-occupied housing, (2) divorce rate, and (3) percent voting in recent presidential elections (an indicator of the potential for collective action).

Forest amenity indicators—A number of variables were selected to provide a general description of the forest landscape: (1) forest land as a percent of all land, (2) pine forest acreage as a percent of total forest acreage, (3) upland hardwood acreage as a percent of total forest acreage, (4) bottomland hardwood acreage as a percent of total forest acreage, and (5) oak-pine acreage as a percent of total forest acreage. Correlations between the degree of industrial concentration in various forest related sectors and these descriptive variables provide us with a general sense of the forest types within which the sectors were concentrated.

The review of the literature linking willingness to pay and forest amenities led us to include variables that would indicate the degree of naturalness of forest ecosystems. Although naturalness may not be possible to define with precision, some aspects can be specified. Anderson's (1991) definition of "natural" was based on the idea that forests that are more natural would change little if removed from human influence and are made up of a high proportion of native species. Noss and Cooperrider (1994) used this idea to define a gradient of forest ecosystem naturalness that ranged from primary natural forests (virtually uninfluenced by human disturbance) to secondary natural forests (natural regeneration after human disturbance) to plantations (human planting after human disturbance).

Using these ideas as broad descriptors of the degree of naturalness, we decided that the following indicators of human disturbance in forest ecosystems should be included: (1) plantation acreage as a percent of all forest acreage,

(2) the change in plantation percent between the two most recent forest surveys, (3) pine removal to pine inventory ratio, (4) pine growth to pine inventory ratio, (5) hardwood removal to hardwood inventory ratio, and (6) hardwood growth to hardwood inventory ratio. The first indicator provides information on the extent of intensive forest management in an area, while the second indicator provides information on the rate of growth of intensive forestry. Removal of pine or hardwood as a proportion of the standing inventory provides information on harvest intensity. Growth as a proportion of standing inventory provides information on the age distribution of forests. Because young forests generally grow more rapidly than old forests, a high/low growth-to-inventory ratio would be found in areas with younger/ older forests.

Data Sources

Four sources of data were used in the analyses. All units of observation were at the county level.

First, data on forest variables were obtained from the Forest Inventory and Analysis (FIA) unit of the USDA Forest Service Southern Research Station on May 26, 1998. The FIA unit conducts periodic forest inventories that rotate throughout the South. Data were not available for all southern counties at the same point in time, so data from the most recent survey were used to provide the most current representation of forest conditions. For one variable, change in plantation acreage, the two most recent forest surveys were used to compute the percent change. Because Kentucky was not included in forest surveys conducted by the FIA unit, forest variables for this State were not directly comparable with other Southern States and were thus not included in the analyses.

The reader should be alerted to the fact that FIA data were sampled in a way to meet sampling error standards at the State level. As data are subdivided into smaller geographical units, such as the county level used in this chapter, the sampling errors increase, and the reliability of the estimates decreases. This may impact the analysis reported in this chapter primarily by increasing the size of the standard errors associated with the Pearson correlation coefficients where such correlations were estimated using forest variables. In turn, an increase in the standard errors associated with correlation coefficients suggests that some relationships that may in fact be statistically significant will not meet the 10-percent significance threshold for reporting in this chapter. However, we do not anticipate this effect will bias the estimated correlations or cause some correlations to appear statistically significant when in fact they are not.

Second, data on employment and income were obtained from the IMPLAN Database (Minnesota IMPLAN Group 1997). To make these data as comparable as possible with data from the most recent census data that were available when the analysis was undertaken (1990), we used 1993 IMPLAN data. Employment data in the IMPLAN Database are created from the Bureau of Labor Statistics ES202 data, the County Business Pattern data provided by the U.S. Department of Census, and the Regional Economic Information System data provided by the Bureau of Economic Analysis. It should be noted that these data are based on where people worked (where the industrial sectors were located), not on where they resided. However, across the entire South, a discrepancy between the county where people worked and where they resided should not be an important issue.

Data on a number of social and economic indicators were obtained from 1990 Bureau of Census data sets. These indicators included: median household income, unemployment rate, poverty rate, and percent of owner-occupied housing. Of course, these data were based on where people resided.

Finally, data on a number of other social variables were obtained from the State and County Data Book (U.S. Department of Census) that was available on the Internet (http://fisher.lib.virginia.edu/ccdb/). In an attempt to align these data with other census data, we chose the most recent data that were closest in date to the 1990 census. Thus, data from the 1994 State and County Data Book were obtained for the following indicators: crime rate (serious crimes per 100,000 population, 1991), percent graduating high school (persons 25 years and older who completed at least high school, 1990), infant mortality rate (deaths of infants under 1 year per 1,000 live births, 1988), percent voting in the most recent presidential election (votes cast for president, 1992, divided by voting-age population, 1992), and percent population change (1980 to 1992).

Results

Linkages Between Forest Dependency and Forest Amenities

Correlations between employment concentration in forest related industries and indicators of forest amenities are shown in table 12.1. The strength of the correlation is greater as the value of the correlation coefficient approaches 1 or –1. A positive value indicates a positive correlation, and a negative value indicates a negative correlation. Correlation coefficients are only shown for values that were statistically different than zero at the 10-percent significance level. Also shown in the table for each statistically significant correlation coefficient is the number of observations (counties) that were used to compute the statistic.

The pulp and paper industry was located in 179 southern counties. Results shown in table 12.1 indicate that the pulp and paper sector was concentrated in heavily forested areas with higher concentrations of pine acreage, plantation acreage, new plantation acreage, and high pine growth to standing inventory ratios. Taken together, these forest indicators suggest that increasing concentration of the pulp and paper industry was correlated with an increasingly industrialized pine forest. Conversely, the results shown in table 12.1 also indicate that the pulp and paper sector was increasingly scarce in areas with higher concentrations of hardwood acreage, particularly upland hardwoods. However, in hardwood forest areas, this sector was found in increasing concentration in areas where removals of hardwoods relative to their standing inventory were high. Thus, although this sector was scarcer in hardwood forest areas than in pine forest areas, in hardwood forest areas where the pulp and paper industry had

Table 12.1—Correlation coefficients relating the level of employment concentration in forest related sectors with various indicators of forest condition (correlation coefficient only reported where statistical significance exceeded 10 percent)[a]

Variable	Pulp and paper sector		Primary wood products sector		Secondary wood products sector		Forest related recreation and tourism sector	
	Correlation coefficients							
Forest	0.19	(170)	0.40	(874)	0.14	(782)	-0.09	(414)
Pine	.20	(169)	.26	(871)				
Plantation	.25	(169)	.29	(871)			-.13	(414)
Change in plantation	.13	(169)	.24	(871)	.06	(777)	-.14	(414)
Hardwood	-.17	(169)	-.27	(871)			.09	(414)
Upland hardwood	-.15	(169)	-.19	(871)	.11	(777)	.10	(414)
Bottomland hardwood					-.13	(777)		
Oak-pine			.10	(871)				
Pine growth/inventory	.17	(164)					-.17	(405)
Pine removal/inventory							-.15	(405)
Hardwood growth/inventory			.06	(871)			-.21	(414)
Hardwood removal/inventory	.27	(169)	.24	(871)			-.19	(414)

[a] Number in parentheses is the number of counties used to compute the correlation coefficient.

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become concentrated, there was a corresponding increase in hardwood harvest intensity.

The primary wood products sector was more widespread than the pulp and paper sector and was located in 978 southern counties. Results in table 12.1 indicate that the primary wood products sector was concentrated in heavily forested areas with relatively higher concentrations of pine acreage, plantation acreage, and new plantation acreage. Conversely, this industry was relatively scarce in hardwood areas, particularly in areas with high concentrations of upland hardwoods. However, concentrations of the primary wood products sector were found in areas with relatively extensive acreage in oak-pine forests. Also, within hardwood forests, increasing concentrations of the primary wood products sector were correlated with increases in harvest intensity as well as increasing forest growth rates. In sum, these indicators suggest that increasing concentration of the primary wood products industry was associated with an increasingly industrialized forest, much as was found for the pulp and paper sector.

The secondary wood products sector was located in 872 southern counties. Results in table 12.1 indicate that the secondary wood products sector was concentrated in heavily forested areas, primarily in areas with high proportions of upland hardwood forests. This result is consistent with the importance to this sector of furniture, millwork, wood containers, and pallets and skids, which are primarily based on a hardwood resource.

The forest related recreation and tourism sector (as defined in this chapter) was located in 414 counties. Results in table 12.1 indicate that the forest related recreation and tourism sector was concentrated in areas with high proportions of hardwood forests, particularly upland hardwood forests. Within hardwood forest areas, this sector was more concentrated where forests were growing relatively slowly (indicating they were older) and where harvest pressure was less intense. Within pine forests, this sector was negatively correlated with extensive forest land managed in plantations and with new plantations. Also, within pine forests, this sector was more concentrated in areas with low rates of pine growth (indicating older forests) and with less intense harvest pressure. In sum, these indicators suggest that increasing concentration of the forest related recreation and tourism sector was associated with an increasingly natural forest.

Linkages Between Forest Dependency and Social, Economic, and Demographic Indicators

Correlations between the degree of industrial concentration in forest related sectors and social, economic, and demographic indicators are shown in table 12.2. The results indicate that job dependency in the pulp and paper sector was correlated with declining levels of median household income, increasing rates of unemployment, increasing rates of poverty, and decreasing rates of high school graduation. [These results are consistent with urban-rural relationships found across the entire South (911 counties). Statistically significant correlation coefficients (at the 0.01 level or higher) were found between population density and median household income (0.41), unemployment (-0.17), poverty rate (-0.26), and educational attainment (0.43). Thus, the degree to which the pulp and paper sector, or other forest products sectors, influenced prevalent economic conditions cannot be easily determined.] Overall, these indicators

Table 12.2—Correlation coefficients relating the level of employment concentration in forest related sectors with various social, economic and demographic indicators (correlation coefficient only reported where statistical significance exceeded 10 percent)[a]

Variable	Pulp and paper sector	Primary wood products sector	Secondary wood products sector	Forest related recreation and tourism sector
	- - - - - - - - - - -	- - - - - - - - - - - *Correlation coefficients*	- - - - - - - - - - -	- - - - - - - - - - -
Population change	-0.13 (179)	-0.21 (978)	-0.12 (872)	0.21 (414)
Unemployment	.18 (179)	.18 (978)		-.14 (414)
Median household income	-.17 (179)	-.29 (978)	-.08 (872)	.27 (414)
Living in poverty	.20 (179)	.28 (978)		-.26 (414)
Infant mortality rate		.06 (978)		
Graduating high school	-.18 (179)	-.25 (978)	-.18 (872)	.37 (414)
Serious crime rate	-.25 (179)	-.27 (978)	-.11 (872)	.29 (414)
Owner-occupied housing	.32 (179)	.24 (978)	.11 (872)	-.15 (414)
Divorce rate		-.13 (978)	-.07 (872)	
Voting-age population voting for President	.26 (179)	.20 (978)		

[a] Number in parentheses is the number of counties used to compute the correlation coefficient.

suggest that this industry was concentrated in areas with limited economic opportunities. However, areas of concentrated employment in this sector were positively correlated with the proportion of residences that were owner-occupied (providing a means of accumulating wealth) and the proportion of the population that voted in presidential elections, and a negative correlation was found with the crime rate. [These results are also consistent with the urban-rural gradient across the South. Statistically significant correlation coefficients (at the 0.01 level or higher) were found between population density and owner-occupied housing (-0.39) and crime rate (0.38). The degree to which the pulp and paper sector, or other forest products sectors, influenced prevalent social conditions cannot be easily determined.] However, the degree of industrial concentration in this sector was negatively associated with the rate of population growth. [Across the South (911 counties), a positive correlation (0.17) was found between population density and the rate of population growth (significant at the 0.0001 level.] This indicator suggests that areas of concentrated employment in the pulp and paper sector were not attracting in-migration to the degree found in areas with lower concentration of employment in this sector.

The results in table 12.2 indicate that variation in economic and social conditions across the degree of job dependency in the primary wood products sector was similar in many respects to the cross-sectional variation in economic and social conditions across the degree of job dependency in the pulp and paper sector. The degree of job dependency in the primary wood products sector was correlated with a decreasing level of median household income, an increase in the poverty rate, an increase in the rate of unemployment, and a decrease in the high school graduation rate. Increasing job dependency in this sector was positively correlated with the proportion of residences that were owner-occupied and the proportion of the population that voted in presidential elections, and a negative correlation was found with the crime rate. Although the divorce rate was found to be relatively lower in areas of concentrated employment in this sector, infant mortality rates were found to be relatively greater. Similar to the result for the pulp and paper industry, we found that the degree of industrial concentration in this sector was negatively associated with the rate of population growth.

The results in table 12.2 indicate that the variation in economic conditions across the degree of job dependency in the secondary wood products sector were similar to relationships found for the pulp and paper and primary wood products sectors. Although increasing job dependency in the secondary wood products sector was negatively correlated with median household income and the proportion of the population that had not completed high school, significant correlations with unemployment rates and the proportion of the population living in poverty were not found. A relatively high proportion of owner-occupied housing was correlated with higher concentrations of employment in this sector, and crime rates and the rate of divorce were negatively correlated with concentration in this industry. However, similar to the other wood products sectors, we found that the degree of industrial concentration in this sector was negatively associated with the rate of population growth.

The results in table 12.2 indicate that job dependency in the forest related recreation and tourism sector was positively correlated with more favorable economic indicators (despite the fact that population density was lower in counties where this sector was located than for the other forestry sectors). An increase in the degree

Table 12.3—Correlation coefficients relating the level of employment concentration in forest related sectors to the level of employment concentration in other economic sectors [a][b]

Variable	Pulp and paper sector	Primary wood products sector	Secondary wood products sector	Forest related recreation and tourism sector
	Correlation coefficients			
Agriculture	0.15 (179)	0.12 (978)		-0.28 (417)
Mining				
Construction		-.17 (978)		.18 (417)
Manufacturing (minus forest products)	-.22 (179)	-.13 (978)		-.15 (417)
Trade			-0.06 (872)	-.11 (417)
Wholesale	-.23 (179)	-.15 (978)	-.14 (872)	.17 (417)
Retail	-.26 (179)	-.24 (978)	-.19 (872)	.38 (417)
Finance, insurance, and real estate	-.32 (179)	-.25 (978)	-.18 (872)	.15 (417)
Service		.05 (978)	-.11 (872)	-.08 (417)
Government		.21 (978)		
Pulp and paper		.12 (978)		
Primary wood products	.26 (179)		.12 (872)	-.25 (417)

[a] Number in parentheses is the number of counties used to compute the correlation coefficient.
[b] Correlation coefficient only reported where statistical significance exceeded 10 percent.

of concentration in the forest related recreation and tourism sector was correlated with increases in median household income and with declining rates of unemployment and poverty. Although crime rates were higher and the proportion of owner-occupied homes was lower in areas where this sector was concentrated, the rate of population growth was found to increase with increasing concentration in this sector. Recall that the results shown in table 12.1 indicated that this sector was concentrated in upland hardwood forest areas that were generally older and under less intense harvesting pressure. Thus, our results are consistent with the conclusions of other studies that found rural population growth was highest for areas with high levels of natural amenities and concentrations of the recreation and tourism industry. In addition, our results suggest that forest related recreation and tourism communities are on a different development path and face different challenges than the wood fiber-based forestry sectors.

Linkages Between Forest Dependency and Economic Structure

Table 12.3 shows the correlation analysis of the degree of concentration in forest related sectors and other economic sectors. Increasing concentration of the pulp and paper industry was positively correlated with the agricultural sector. This is not surprising, as many of the pine forests in the South are found where agricultural fields were abandoned.

Increasing concentration in the pulp and paper industry was negatively correlated with a number of economic sectors including manufacturing; wholesale; retail; and finance, insurance and real estate. The generally rural location of the pulp and paper sector probably explains the relative scarcity of the wholesale and retail sectors. The relative scarcity of the finance, insurance, and real estate sector also probably reflects the lower level of economic development in areas where the pulp and paper sector was concentrated.

Two factors that are sought in locating pulp and paper plants are an available water supply (used in processing) and good access to transportation networks so that wood fiber can be procured efficiently and products can be readily shipped to market. Because the manufacturing sector also relies on good market access, it is perhaps surprising that a negative correlation was found between the pulp and paper sector and the manufacturing sector. However, this result may reflect a situation where, in locations that are close to a suitable supply of wood fiber, the pulp and paper industry is more competitive in the labor market than are other manufacturing sectors. Average income per job in the pulp and paper sector was considerably higher than average income for the typical job in areas where that sector was located (table 12.4). This is due to the large amount of industrial capital invested in the pulp and paper sector that in turn increases labor productivity.

The results in table 12.3 show that the degree of industrial concentration in the primary wood products sector was positively correlated with concentration in the agricultural sector. Again, this probably reflects the historical conversion of old fields to pine forests.

Table 12.4—Comparison of income per job in forest related sectors and typical jobs in counties where forest related sectors were located

Forest related sector	Counties where industry located	Forest related sector, income per job	Typical job, income per job
	Number	*- - - - - - Dollars per year - - - - -*	
Pulp and paper	179	54,760.00	22,211.03
Primary wood products	978	19,300.36	19,193.03
Secondary wood products	872	21,844.66	19,549.69
Forest related recreation and tourism	414	9,881.54	18,492.17

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The negative correlation with wholesale and retail sectors probably reflects the rural location of this sector. The negative correlation with the finance, insurance, and real estate sector and with the construction sector reflects the relatively low level of economic development in areas where the primary wood products sector was found. Because the primary wood products sector supplies inputs to the pulp and paper sector, it was not surprising to observe a positive correlation between the two industries.

Similar to the pulp and paper sector, the negative correlation of the primary wood products sector with the manufacturing sector may indicate that this sector was more competitive in the market for labor. However, as shown in table 12.4, average income per job in the primary processing sector was only slightly higher than average income for the typical job in areas where the primary processing sector was located. However, many of the firms that constitute this industry are relatively small, such as logging contractors and sawmills. The relative independence and way of life afforded by working in this sector may be particularly appealing to members of the workforce in these rural areas.

It is important to note that the negative correlation between the pulp and paper and primary wood products sectors and the manufacturing sector suggests that the forest products industry contributes an increased share to the economic base of those areas. In the South as a whole, manufacturing constitutes the largest sector in the economic base. The substitution of forest products sectors for manufacturing suggests that in areas with concentrated employment in those forest products industries, local economies are relatively more dependent on the income and employment generated by the harvest and processing of timber and timber products.

Industrial concentration in the secondary wood products sector was negatively correlated with the wholesale and retail sectors reflecting the relatively low population density in those areas. Relatively low levels of economic development in areas of concentrated employment in the secondary wood products sector was reflected in the negative correlations with the finance, insurance, and real estate sector and with the construction sector. Because the secondary wood products sector uses inputs supplied by the primary wood products sector, it was not surprising to find a positive correlation between these two sectors.

The fact that the forest related recreation and tourism industry was positively correlated with upland hardwood forests that were older and under relatively less harvest pressure suggests that a negative correlation between this sector and the primary wood products sector would exist. This is what was found. Likewise, the concentration of the forest related recreation and tourism industry in these types of forests suggests a negative correlation with agriculture, which was also found. The higher level of economic development associated with this industry was reflected in the positive correlations with the finance, insurance, and real estate sector and the construction sector. Further, the outputs of this industry are consumed directly by consumers. The positive correlation with the retail and wholesale sectors reflects complementary consumption within those sectors and the forest related recreation and tourism sector.

Income per job in the forest related recreation and tourism sector was quite a bit less than income per typical job in the areas where that sector was found (table 12.4). This may reflect the seasonality or part-time nature of some jobs in this sector. Also, we note that some people are willing to accept lower monetary compensation to work in an industry that is located in an area where the natural amenities supply other forms of compensation contributing to real income.

Discussion and Conclusions

The forest products industry, comprising the primary and secondary wood products sectors and the pulp and paper sector, contributes to local economies in forested areas in the Southern United States. Although average job dependency (the ratio of forest sector jobs to total employment) was found to be modest, the forest products industry offered good paying jobs in areas where other economic opportunities were limited. (In counties that had forest related employment, average job dependency was 3.0 percent in the pulp and paper sector, 2.0 percent in the primary wood processing sector, 1.6 percent in the secondary wood processing sector, and 4.9 percent in the forest related recreation and tourism sector.) On average, income per job in this industry ranged from marginally higher (in the primary and secondary wood products sectors) to much higher (in the pulp and paper sector) than income per job for the typical source of employment (that is, average income per job over all sectors). By providing good paying jobs, the quality of life was enhanced for people who worked in this industry.

Through the export of wood products to other regions, the forest products industry also contributed to local economies by bringing in income to economies where the forest products industry was located and by contributing to the local tax base. Some understanding of the contribution this industry made to local economies can be gained by considering the economic base in areas where the primary and secondary wood products sectors and the pulp and paper sector constitute at least 10 percent of total employment. Using the standard assumption that agriculture, mining, nonwood manufacturing, and the forest products industry make up the economic base (Crone and others 1999), the forest products industry accounted for about 62 percent of employment in basic industries in areas where the pulp and paper industry constituted at least 10 percent of total employment (19 counties). In areas where the primary wood products sector constituted at least 10 percent of total employment (32 counties), the forest products sector accounted for about 54 percent of employment in basic industries. In areas where the secondary wood products sector constituted at least 10 percent of total employment (14 counties), the forest products sector accounted for about 52 percent of employment in basic industries.

However, forests contributed to quality of life in the South in more ways than simply providing income and employment. For many people, enjoyment of the amenities provided by natural forest environments enhanced their quality of life. The list of forest amenities that improved the quality of life in the South include scenic views, opportunities for outdoor recreation, provision of habitat for endangered species and other wildlife, and enhancement of water quality and quantity.

One way of evaluating the contribution of forest amenities to quality of life is to consider some of the characteristics associated with forest related recreation and tourism communities. It was found that increasing concentrations of jobs in the forest related recreation and tourism sector was associated with increasing proportions of upland hardwood forests, increasing age of forests (that is, they were slower growing), decreasing timber harvesting pressure, and decreasing proportion of forest acreage in pine plantations. In general, these forest areas can be considered to be more natural, in the sense that they have received less human-induced disturbance, and provide greater levels of forest amenities.

We found that increasing concentration of employment in the forest related recreation sector was associated with better economic conditions (higher median household income and lower rates of poverty and unemployment). We also found that as the concentration of employment in the forest related recreation sector increased, population growth also increased. This result suggests that people moved to rural areas with more natural forest amenities to improve their quality of life.

Competing demands on southern forests will likely increase as timber production intensifies in the South due to the region's competitive advantage in timber growing and as people continue to move to locations in the South that provide natural forest amenities. In some areas these trends will intensify the social, political, and ideological tensions related to forest use. And in some areas, quality of life for residents may decline where forests with natural amenity values come under increased pressure for timber harvest and intensified forest management. We suggest that research, education, and public discourse are the primary tools that can help identify and resolve issues related to future forest conditions and uses in the South.

Needs for Additional Research

The valuation of public goods provided by private forests in the South is an area of research that has not been explored but is clearly needed. This research needs to identify values associated with forest land use and land use change across various strata including forest type, geographic location, and population density. For example, concern has been raised in the South about the impact that timber harvesting and intensified forest management may have on forest landscapes and how such changes impact the provision of public goods and forest amenities from private forests. The degree of concern about timber harvesting and intensified forest management may not be evenly spread across people living in the South. A better understanding of who is concerned about the intensification of forest management, why they are concerned, where they are concerned, and how much they are concerned will help develop meaningful communication between citizens and policymakers.

A better understanding of forest values produced by private forest land could then be used to assess which areas in the forest landscape would provide the greatest contributions to sustainable economic growth and development. Any attempt to increase the quality of life in forest environments must consider the full spectrum of forest uses from natural forests to plantations. Further research can help provide relevant information to local, regional, State, and Federal agencies with the intent of designing land management plans that are in keeping with the values and goals of all people living in the South.

Another area of research that is needed is to develop a better understanding of the dynamics of economic development in communities with forest related industries. The dynamic relationships between forest related industries in the South and prevalent social and economic conditions are generally unknown and cannot be easily determined. However, it appears that areas with high concentrations of timber-based industries and areas with high concentrations of forest related recreation employment face different paths of economic development. This is typified by a disparity in rates of population growth and economic and social indicators between the timber-based and recreation-based forest sectors. Identifying obstacles to and opportunities for quality growth in forested communities in the South is an important research endeavor.

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Literature Cited

American Forest & Paper Association. 1994. Closer look—an on-the-ground investigation of the Sierra Club's book, Clearcut. Washington, DC: American Forest & Paper Association. 28 p.

Anderson, J.E. 1991. A conceptual framework for evaluating and quantifying naturalness. Conservation Biology. 5: 347–352.

Arrow, K.J. 1983. Social choice and justice. Cambridge, MA: Harvard University Press, Belknap Press. 229 p.

Backiel, A.; Gorte, R.W. 1992. Clearcutting in the national forests. Washington, DC: Congressional Research Service Report for Congress. National Council for Science and the Environment: Washington, DC. 26 p. http://www.cnie.org/nle/crsreports/forests/for-2.cfm. [Date accessed June 2001].

Bayless, M.; Bayless, S. 1982. Current quality of life indicators: some theoretical and methodological concerns. American Journal of Economics and Sociology. 41: 421–437.

Beale, C.L.; Johnson, K.M. 1998. The identification of recreational counties in nonmetropolitan areas of the U.S.A. Population Research and Policy Review. 17: 37–53.

Boyer, R.; Savageau, D. 1981. Places rated almanac. Chicago: Rand McNally. [Number of pages unknown].

Boyle, K.J.; Holmes, T.P.; Teisl, M.F.; Roe, B. 2001. A comparison of conjoint analysis response formats. American Journal of Agricultural Economics. 83: 441–454.

Boyle, K.J.; Teisl, M.F. 1999. Public preferences for timber harvesting on private forest land purchased for public ownership in Maine. Misc. Rep. 414. Orono, ME: Maine Agricultural and Forest Experiment Station. 18 p.

Cobb, C.; Halstead, T.; Rowe, J. 1995a. The genuine progress indicator: summary of data and methodology. San Francisco: Redefining Progress. [Number of pages unknown].

Cobb, C.; Halstead, T.; Rowe, J. 1995b. If the GDP is up, why is America down? Atlantic Monthly. October. 59–78.

Cook, P.J.; Mizer, K.L. 1994. The revised ERS county typology. Rural Dev. Res. Rep. 89. Washington, DC: U.S. Department of Agriculture, Economic Research Service. [Number of pages unknown].

Cordell, H.K.; Bergstrom, J.C., eds. 1999. Integrating social science with ecosystem management: human dimensions in assessment, policy, and management. Champaign, IL: Sagamore Publishing. [Number of pages unknown].

Crone, L.K.; Haynes, R.W.; Reyna, N.E. 1999. Different perspectives on economic base. Res. Note PNW–RN–538. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 21 p.

Dasgupta, P. 1999. Valuation and evaluation: measuring the quality of life and evaluating policy. Discuss. Pap. 127. Stockholm: Beijer International Institute of Ecological Economics. 69 p.

Deller, S.C.; Tsai, T-H; Marcouiller, D.W.; English, D.B.K. 2001. The role of amenities and quality of life in rural economic growth. American Journal of Agricultural Economics. 83: 352–365.

Devall, B., ed. 1993. Clearcut: the tragedy of industrial forestry. San Francisco: Sierra Club Books/ Earth Island Press. 291 p.

Diener, E. 1995. A value-based index for measuring national quality of life. Social Indicators Research. 36: 107–127.

Driver, B.L.; Brown, P.J.; Peterson, G.L., eds. 1991. Benefits of leisure. State College, PA: Venture Publishing. [Number of pages unknown].

Driver, B.L.; Dustin, D.; Baltic, T. [and others], eds. 1996. Nature and the human spirit: toward an expanded land management ethic. State College, PA: Venture Publishing. [Number of pages unknown].

Easterlin, R. 1974. Does economic growth improve the human lot? Some empirical evidence. In: Nations and households in economic growth. New York: Academic Press. [Number of pages unknown].

English, D.B.K.; Bergstrom, J.C. 1994. The conceptual links between recreation site development and regional economic impacts. Journal of Regional Science. 34: 599–611.

English, D.B.K.; Marcouiller, D.W.; Cordell, H.K. 2000. Linking local amenities with rural tourism incidence: estimates and effects. Society and Natural Resources. 13: 185–202.

Ferriss, A.L. 2000. The quality of life among U.S. States. Social Indicators Research. 49: 1–23.

Freeman, A.M., III. 1993. The measurement of environmental and resource values—theory and methods. Washington, DC: Resources for the Future. 516 p.

Garoogian, R.; Garoogian, A.; Weingart, P.W. 1998. America's top-rated cities: a statistical handbook. Boca Raton, FL: Universal Reference Publications. [Number of pages unknown].

Garrod, G.D.; Willis, K.G. 1997. The nonuse benefits of enhancing forest biodiversity: a contingent rank study. Ecological Economics. 21: 45–61.

Gobster, P.H. 1999. An ecological aesthetic for forest landscape management. Landscape Journal. 18: 56–64.

Haefele, M.; Kramer, R.A.; Holmes, T. 1992. Estimating the total value of forest quality in high-elevation spruce-fir forests. In: The economic value of wilderness: Proceedings of the conference. Gen. Tech. Rep. SE–78. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 91-96.

Hamilton, J.T. 1993. Politics and social costs: estimating the impact of collective action on hazardous waste facilities. RAND Journal of Economics. 24: 101–125.

Hamilton, J.T. 1999. Exercising property rights to pollute: do cancer risks and politics affect plant emission reductions? Journal of Risk and Uncertainty. 18: 105–124.

Holmes, T.P.; Boyle, K.J. 2002. Using stated preference methods to estimate the value of forest attributes. In: Sills, E.O.; Abt, K.L., eds. Forests in a market economy. Dordrecht, The Netherlands: Kluwer Academic Publishers. [Number of pages unknown].

Holmes, T.P.; Kramer, R.A. 1996. Contingent valuation of ecosystem health. Ecosystem Health. 2: 56–60.

Johnson, K.M.; Beale, C.L. 1994. The recent revival of widespread population growth in nonmetropolitan areas of the United States. Rural Sociology. 59(4): 655–667.

Kalbfleisch, J.G. 1985. Probability and statistical inference. New York: Springer-Verlag. 343 p.

Kramer, R.A.; Holmes, T.P.; Haefele, M. 2002. Using contingent valuation to estimate the value of forest ecosystem protection. In: Sills, E.O.; Abt, K.L., eds. Forests in a market economy. Dordrecht, The Netherlands: Kluwer Academic Publishers. [Number of pages unknown].

Krutilla, J.V. 1967. Conservation reconsidered. American Economic Review. 57: 777–786.

Krutilla, J.V.; Fisher, A.C. 1985. The economics of natural environments—studies in the valuation of commodity and amenity resources. Washington, DC: Resources for the Future. 300 p.

Minnesota IMPLAN Group, Inc. 1997. IMPLAN professional social accounting & impact analysis software. Stillwater, MN.

Miringoff, M.; Miringoff, M-L. 1999. The social health of the nation: how America is really doing. New York: Oxford University Press. [Number of pages unknown].

Morgan Quinto Corporation. 1998. State rankings 1998. Lawrence, KS: Morgan Quinto Corporation. [Number of pages unknown].

Mukherjee, R. 1989. The quality of life: valuation in social research. Newbury Park, CA: Sage Publications. [Number of pages unknown].

Niemi, E.; Whitelaw, E. 1999. Assessing economic tradeoffs in forest management. Gen. Tech. Rep. PNW–GTR–403. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 78 p.

Noss, R.F.; Cooperrider, A.Y. 1994. Saving nature's legacy—protecting and restoring biodiversity. Washington, DC: Island Press. 416 p.

Parkins, J. 1999. Enhancing social indicators research in a forest-dependent community. The Forestry Chronicle. 75: 771–780.

Pearse, P.H.; Holmes, T.P. 1993. Accounting for nonmarket benefits in southern forest management. Southern Journal of Applied Forestry. 17: 84–89.

Power, T. 1996. Lost landscapes and failed economies: the search for a value of place. Washington, DC: Island Press. 313 p.

Power, T.M. 1980. The economic value of the quality of life. Boulder, CO: Westview Press. [Number of pages unknown].

Richmond, L.; Filson, G.C.; Paine, C. [and others]. 2000. Non-farm rural Ontario residents' perceived quality of life. Social Indicators Research. 50: 159–186.

Ross, P.J.; Green, B.L. 1985. Procedures for developing a policy-oriented classification of nonmetropolitan counties. Staff Rep. AGES850308. Washington, DC: U.S. Department of Agriculture, Economic Research Service. [Number of pages unknown].

Schallau, C. 1994. The contribution of the forest products industry to rural economies of the Southern Appalachian region. Tech. Bull. 94–4. Washington, DC: American Forest & Paper Association. 52 p.

United Nations Development Program. 1998. Human development report. New York: Oxford University Press. [Number of pages unknown].

Walsh, R.G.; Bjonback, R.D.; Aiken, R.A.; Rosenthal, D.H. 1990. Estimating the public benefits of protecting forest quality. Journal of Environmental Management. 30: 175–189.

Wish, N.B. 1986. Are we really measuring the quality of life? Well-being has subjective dimensions, as well as objective ones. American Journal of Economics and Sociology. 45(1): 93–99.

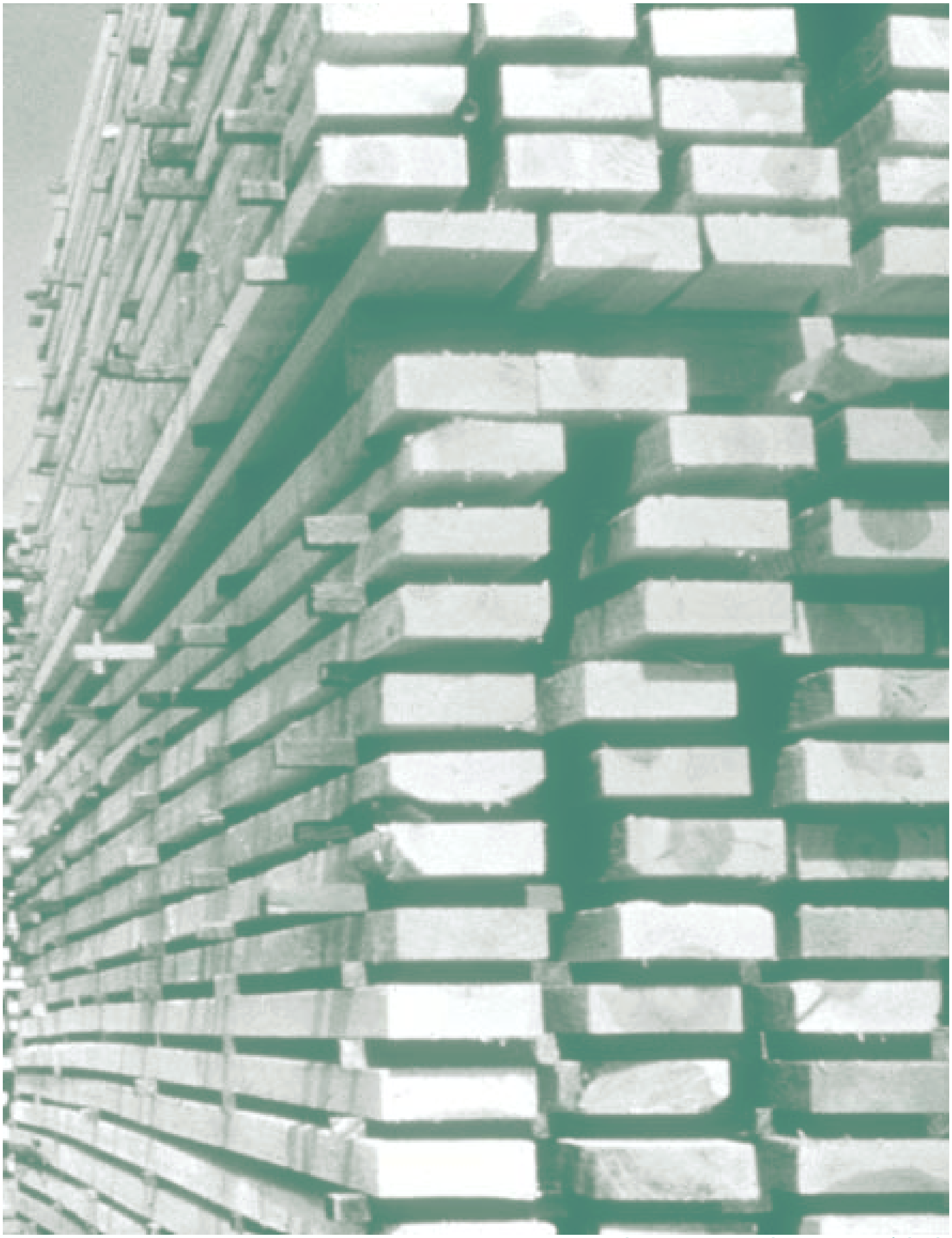
Photo courtesy Tim White, University of Florida

TIMBER

What are the history, status, and projected future demands for and supplies of wood products in the South?

Chapter 13: Timber Products Supply and Demand

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Key Findings

■ The South produces approximately 60 percent of the Nation's timber products, almost all of it from private forests; the South produces more timber than any other single country in the World, and it is projected to remain the dominant producing region for many decades to come.

■ Timberland area is projected to increase in many parts of the South, especially in western and northern portions, due to agricultural land conversion to forest and to tree planting. Timberland will be lost, especially to urban and residential land uses and especially in the Piedmont region (Virginia to Georgia) and in Florida. The net effect of losses and gains is no significant change in timberland area under two plausible scenarios. However, in aggregate in the South, nonplantation timberland acreage is projected to decline by an average of 15 percent under all market and plantation growth scenarios considered.

■ Production of both hardwood and softwood timber is projected to increase Southwide, but the largest percentage increases are projected for northern and western portions of the region, especially in Alabama, Arkansas, Kentucky, Tennessee, and Virginia.

■ Timber prices are projected to increase in the United States and the South over the next 40 years under two plausible scenarios. The price rises serve as continued incentives for private timberland owners to keep land in forest in some places, to improve timber growing and wood-processing productivity, and to heavily invest in timber growing technology and intensive forest management.

■ Private landowners in the South are projected to continuously expand areas of pine plantations in the region far into the future. An outcome of this is a projected increase in the area of pine plantations—in the base scenario, by 67 percent (from 33 to 54 million acres) between 1995 and 2040.

Introduction

This chapter describes historical, current, and projected timber inventories and timber product outputs from southern forests. It also attempts to place these quantities in national and international perspectives. Timber is the most valuable commercial commodity taken from most forests, and its removal strongly influences the character of those forests. Timber is removed to convert land to other uses, and it is removed in regular harvest activities of managed forests. These two processes do not occur randomly on the landscape. Rather, they occur in patterns that are predictable, related to the locations of development, timber processing capacities, and the species in demand for timber products. Because removals are a function of societal demands, the products made from timber, and the technologies used to remove and process timber, the nature of forests and projected future of those forests can be traced out by relating economic and demographic trends to the timber products sector. The economic and demographic relationships to the timber sector can be identified through a description of historical patterns of timber production and technologies. Hence, such a description provides substantial information for predicting the future of southern forests.

In describing the history and projected future of southern forests and their associated timber markets, technical terminology is often used. For clarity, it is worth defining some frequently used terms. Demand is the schedule of quantities that would be purchased by consumers over a range of prices. Supply is the schedule of quantities that would be produced in a geographic region by product manufacturers over a range of prices. Production is defined as the amount that is actually produced in a geographic region, and consumption is how much is actually purchased by consumers in a geographic region. If a country or a State consumes more than it produces of a given product, then it is a net importer of that product. If it produces more than it consumes, then it is a net exporter. The incentive for a country or State to produce a different quantity from what it consumes arises out of the ability of buyers and sellers to move products back and forth across national borders and State lines profitably. We use the definition of forest land and timberland as adopted by the USDA Forest Service in its Resources Planning Act (RPA) documents and its own projections. See chapter 16 for a thorough definition of each.

To address questions of historical and future supplies and demands for timber products, six steps were taken:

- Historical production levels were described for the South's major species groups and timber products, including pulpwood, sawtimber, residues, fuel wood, and other fiber products. Southern production was sometimes contrasted with similar production occurring elsewhere in the country.
- The linkages to international markets were evaluated, and implications of changing wood products exports and imports of competing materials were considered.
- Market linkages with other parts of the United States were evaluated.
- Projections of future timberland areas by major forest types, timber inventories, timber growth, timber removals (production), and timber prices were made under a base scenario of supply-and-demand assumptions and under three alternative scenarios. Projections for the South were put into additional context with the rest of the Nation and the World by reporting some findings of the 2000 Draft RPA assessment (Haynes and others 2002).
- Possible effects of land use change on timber supplies were evaluated.
- The impacts of changes in intensity of forest management and in forest productivity on timber supply and forest composition were described.

Data and space limitations constrained the extent and detail of information to provide. The chapter does not describe every issue of historical, current, or potential future importance for the South's forests. Further, a lack of data on historical production and consumption patterns limited opportunities to describe and draw conclusions about some important trends and relationships. The primary sources of data for the chapter are given, however, for those who wish to pursue certain issues in detail. Similarly, the methods of analysis are outlined rather than explained in detail. Details are to be found in the cited literature. Finally, those interested in broader, national projections and details about other regions of the United States are directed to the 2000 RPA assessment (Haynes and others 2001).

As in the rest of this Assessment, this chapter does not evaluate policies or make policy recommendations. Those interested in conducting these kinds of analyses, however, may find the material presented here to be useful starting points.

Methods

Much of this chapter is concerned with projections of the future. Because projecting the future is controversial and complex and always subject to great uncertainties, some explanation of projection procedures is warranted. Trends in the southern timber sector were projected with a partial equilibrium model of the southern forest sector, the Subregional Timber Supply Model (SRTS) of Abt and others (2000). Nonproductive forest land and public timberlands are not modeled by SRTS. Hence, SRTS provides projections of private timber inventories, growth, removals, prices, land use, and timberland area by five broad forest management types at sub-State and ecoregion (Bailey 1995) levels. The SRTS projections are based on the results of empirical models of timber and land supply-and-demand relations to prices, income, and other variables. The projection period for this Assessment had a starting point of 1995 and an ending point of 2040. Data on public timberland and nonproductive forest land are not included in the projection or any of the accompanying results.

SRTS consists of four models (fig. 13.1): (1) a timber inventory model, which projects each year's softwood (coniferous) and hardwood (non-coniferous) timber growth (net after mortality) on existing acres, based on a set of growth equations and on the previous year's harvests of softwood and hardwood; (2) a stumpage market model consisting of supply-and-demand curves for timber softwood and hardwood timber harvests, which determines the amount of harvests, the timber prices, and the volume and the state of the inventory in softwood and hardwood; (3) a pine plantation allocation model, which determines how many acres of pine trees to plant, given the softwood price and other factors; and (4) a timberland allocation model, which determines how much private land is devoted to forest and allocates that land to either timberland or nonproductive forest land, given timber prices, financial returns to agricultural land uses, and other factors. For each year of the projection, SRTS solves for the combination of Southwide softwood and hardwood timber prices, softwood and hardwood timber harvests, pine tree planting acres, and total timberland area that makes the supply of timber equal its demand. Although land use is projected at the county level, the precision of historical inventory and harvest data limits the smallest unit of inference for the projected variables in the model to the USDA Forest Service, Southern Research Station, Forest Inventory and Analysis survey unit (FIA).

The primary outputs of the model are annual values of: (1) timberland area by five forest management types (pine plantation, natural pine, mixed oak-pine, upland hardwood, and bottomland hardwood) by survey unit; (2) a single-volume measure of timber growth, removals, and inventory by management type, survey unit, and owner; and (3) indices of Southwide aggregate softwood and hardwood

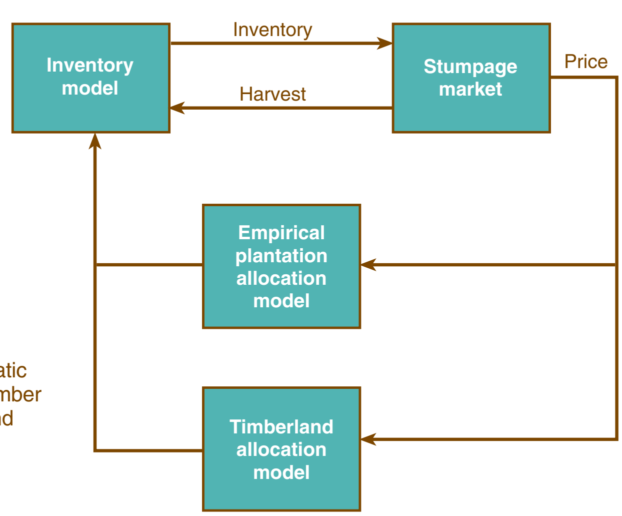

Figure 13.1—Schematic of the Subregional Timber Supply model (Abt and others 2000).

timber prices. Because these projected variables are outcomes of the model, they may all be termed endogenous (that is, determined by the model). Two exceptions on the endogeneity of land use were Kentucky after 2020 and Oklahoma for the entire projection period. Data limitations permitted projections of Kentucky's land use allocation only through 2020, but remained fixed thereafter. Oklahoma did not have an applicable land use model, so that portion of Oklahoma that was included in this Assessment had land use (and, hence, timberland areas by owner and survey unit) fixed at observed 1993 levels during the entire projection period.

SRTS has several exogenous inputs—prespecified model parameters and the levels and trends of certain variables that set the context of the model solution. While the model parameters, which quantify the relationships among endogenous and exogenous variables, are held constant, alternative levels of some of the exogenous variables and some model parameters collectively define four projection scenarios (table 13.1). One exogenous variable is timber demand growth over time, a forecast of how the demand curves for hardwood and softwood timber shift each year. This was specified as a 1.6 percent annual expansion in demand. The rate of annual timber demand growth was based on historical trends and historical relationships among population growth, technological change, and timber product consumption patterns. Also, this growth rate is roughly the same as that specified for the South in the Draft RPA 2000 assessment. The exogenous determination of timber demand growth implies that the model takes the rest of the World as given, so that the model does not feed back to other regions when calculating its annual

Table 13.1—Subregional Timber Supply Model assumptions

Variable	Scenarios	Species	Ownership	Value	Source of the assumption
Assumed annual outward shift (increase) in timber demand	All	All	All	1.6%/yr	1993 RPA
Southern pine plantation area elasticity with respect to timber price	All	All	Industry	0.60	Murray and Lee (1990)
	All	All	NIPF	1.8	Murray and Lee (1990)
Timberland area elasticity with respect to timber price	All	All	All	~.3	Hardie and others (2000)
Rural area elasticity with respect to population, income, and agricultural rents	All	All	All	Imbedded	Hardie and others (2000)
Supply price elasticity	All	Hardwood	All	.45	Adams and Haynes (1996)
	All	Softwood	All	.29	Adams and Haynes (1996)
Demand price elasticity	IH	All	All	-.50	Abt and others (2000)
	IL	All	All	-.50	Abt and others (2000)
	EH	All	All	-5.00	This Assessment
	EL	All	All	-5.00	This Assessment
Southern pine plantation growth rates					
	IH	All	Industry	75% by 2040	This Assessment
	IH	All	NIPF	37.5% by 2040	This Assessment
	IL	All	Industry	50% by 2040	This Assessment
	IL	All	NIPF	25% by 2040	This Assessment
	EH	All	Industry	75% by 2040	This Assessment
	EH	All	NIPF	37.5% by 2040	This Assessment
	EL	All	Industry	50% by 2040	This Assessment
	EL	All	NIPF	25% by 2040	This Assessment

NIPF = nonindustrial private forest; IH = (base case) inelastic timber demand and high plantation volume growth rates; IL = inelastic timber demand and low plantation volume growth rates; EH = elastic timber demand and high plantation volume growth rates; EL = elastic timber demand and low plantation volume growth rates.

combinations of timberland acres by management type, timber harvest volumes, and prices. The exogenous determination of demand growth therefore does not allow southern timber prices to induce technology changes in the product manufacturing sector, nor does it allow timber prices to directly affect the rate of substitution of other raw materials or nonsouthern virgin wood fiber for southern virgin wood fiber in forest product manufacturing, except to the extent that the historical rate of timber demand growth embodies the historical rate of product substitutions and technology changes. An accounting for those kinds of feedback might be justified if the South were a small region compared to the rest of the country (or if model complexity were unrelated to model accuracy). However, the South dominates the U.S. timber market, so the exogenous demand growth determination can be viewed as a reasonable approximation of true national market functions.

Also predetermined prior to solving the SRTS model for the 45 years of projection is a set of variables involved in the land use allocations. These variables include projections of population growth, aggregate U.S. economic growth, agricultural rents (the real annual monetary returns to using land to produce an agricultural output), and residential land rents (see chapter 10 for a more detailed discussion of the land use module). Agricultural rents were specified as constant (in real terms) over the entire projection period. Another key exogenously determined variable in the SRTS projection is the rate of increase in the growth rate of pine plantations in the South. Underlying projection parameters and inputs used in the SRTS model projections for the South are shown in table 13.1.

Although four scenarios were modeled in this Assessment, one, abbreviated IH for "inelastic demand-high plantation growth rate increase," is designated as the "base case" for two reasons. First, the inelastic demand assumption is consistent with empirical findings of responses of demand to prices and is consistent with assumptions of RPA projections. Second, the SRTS model authors determined, through informal surveys of industry and pine plantation experts in the South, that the higher plantation volume growth rate increases (75 percent for industry plantations and 37.5 percent for nonindustrial private plantations) are closest to a lower bound on plantation growth rate increases expected over the period. These alternative scenarios were performed to demonstrate the marginal effects of plantation growth rates and timber demand elasticities on important model outputs. Results from the base case scenario are discussed first. Some of the results are contrasted with results for the other scenarios, and figures describing the results of other scenarios are also made available to the reader.

As with many forecasting models, an underlying assumption in SRTS for this Assessment is that timber supply-and-demand and land use supply-and-demand relationships remain stable. In that sense, the projections do not account for changes in the share of the available or harvestable timber out of all timberlands owned by various owner categories (including government, industry, and nonindustrial private). Neither do the projections incorporate any predicted changes in wood product substitutes, wood product manufacturing technologies, real costs of timber management or production, or consumer tastes and preferences. Finally, the projections do not incorporate the effects of any expected changes in industrial structure in the paper or other industries. To the extent that such structural changes in these sectors affect assumed underlying supply and demand parameters, our projections are inappropriate. When interpreting the projections reported in this chapter and projections reported elsewhere, it is important to consider that projections and their underlying assumptions about economic variables become less and less reliable as the length of the projection increases.

SRTS has been designed to describe projections of the future for small regions or specific parts of the South. The FIA boundaries divide each Southern State into three to six sections, whose boundaries follow county lines but generally divide the States into physiographic regions. An advance of SRTS from the projections provided in Abt and others (2000) is that this version of SRTS now permits reporting of outputs by spatial units called ecological regions (Bailey 1995), which are not associated with political boundaries. As it turns out, ecological region boundaries follow survey unit boundaries fairly closely, as both division structures are based on many of the same factors. Given this, little of what is reported in this chapter actually is described in the context of ecological regions, though the data outputs could be reorganized in that fashion.

Data Sources

Data on international trade in timber products were obtained from the United Nations Food and Agricultural Organization (2000a). Historical national forest timber harvest data were obtained directly from the National Forest System's fourth quarter annual totals in the cut-and-sold reports (U.S. Department of Agriculture Forest Service 2000). National-level historical harvest and wood use and productivity information was provided by the Forest Products Laboratory (Personal communication. [2000]. Kenneth Skog, Project Leader, and Peter Ince, Research Forester, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705) and from supporting documents (Ince 2000). Pulpwood production data for the South are from Johnson (1996), Johnson and Howell (1996), and Johnson and Steppleton (1996, 1997, 1999, 2000). Removals data by type of product were provided by the U.S. Department of Agriculture Forest Service (1958, 1982), Hair (1963), Phelps (1980), Waddell and others (1989), Powell and others (1994), and Haynes and others (2001). Draft 2000 RPA projection information was obtained from Haynes and others (2002).

Input data for all SRTS projection scenarios derived from the plot-level data from the latest FIA surveys available at the time of the projection for each State in the South. The years of the latest surveys used are displayed concisely in the last two columns of a table reported in chapter 16, 1970s to 1999. The later of the two surveys were as follows: Alabama 1990, Arkansas 1995, Florida 1995, Georgia 1998, Kentucky 1988, Louisiana 1991, Mississippi 1994, North Carolina 1990, Oklahoma 1993, South Carolina 1993, Tennessee 1999, Texas 1992, and Virginia 1992. The next most recent survey for each State frames the years between which growth and removals information was obtained for the purposes of this analysis. While the oldness of certain surveys leads to potential inaccuracies due to more recent trends in those States, this was beyond our control.

Results

History and Current Status of Supply and Demand

World demand and supply history and status—The United States is the largest producer of industrial timber in the World. For the last 40 years, it has produced a fairly stable 25 percent of total World production of industrial roundwood (United Nations Food and Agricultural Organization 2000b). In 1999, the World produced about 53.2 billion cubic feet (bcf), while the United States produced 15.1 bcf, or 28.5 percent of the total. The second largest producer, Canada, produced about 12 percent (6.4 bcf) of the industrial roundwood in 1999. In order, the next most important were China (3.6 bcf), Brazil (1.9 bcf), Sweden (1.9 bcf), and Finland (1.8 bcf).

Although those countries are major producers, domestic demands in those countries greatly influence their stature in international markets for timber products. Observed trade flows in wood and paper products Worldwide (table 13.2) can largely be ascribed to differences among countries in size of demand, amount of forest or timberland, and distance between trading partners (Bonnefoi and Buongiorno 1990). Besides these fundamental factors, trade is affected by government policies such as tariffs and nontariff barriers. Timber products trade also seems to be related to historical political relationships (Castillo and Laarman 1984).

The large size of the United States forest resource helps to determine why the country produces so much, while the size of its domestic economy helps explain why it imports so much. How much a country imports and exports is determined by whether the country's domestic manufacturers supply more than the country's domestic consumers demand at current prices. Countries with reasonably free trade typically do not demand exactly what domestic producers supply. Thus, although the United States because of its extensive forest resources is the World's biggest producer and second largest exporter, after Canada, the relatively free flow of imports, large population, and high per capita income enable the United States to be the World's largest timber product importer. To illustrate, in the past decade and in terms of dollar value, the United States imported 60 percent more timber products than it exported.

The costs of product movement are why the distance between markets plays a role in determining both the scale of trade and specific trading partners. Usually, the closer physically that two trading partners are, the lower the transport cost. Canada and the United States possess the largest bilateral trade flow, partly because the two countries have a long common border. Proximity also explains partly why virtually every country south of the United States border counts the United States as both its primary source of timber product imports and its principal destination of timber products exports. In Asia and Europe, the dominant trade flow is from nearby Asian supply sources (Indonesia, Malaysia, New Zealand, and Russia) to nearby demand centers.

Both the volume and value of timber products trade have been growing rapidly Worldwide, and so trade is becoming more important in many countries as an influence on their forest sectors. Rapid trade growth can be ascribed both to overall World economic growth and to decreasing barriers to international trade. Tariffs on timber products have been decreasing Worldwide, as a result of consecutive rounds of the General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO) (Barbier 1996).

The United States trades in all kinds of timber products. In terms of value, the most important exports are wood pulp, printing and writing paper, and hardwood lumber. United States exports go predominantly to Europe, Canada, Japan, Mexico, the rest of Latin America, and the Caribbean. The most important imports are softwood lumber, newsprint, printing and writing paper, and wood-based panels. Nearly

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Table 13.2—Direction of trade among major timber products trading countries, 1997

	Importer								
Exporter	Brazil	Canada	Europe	Indonesia	Japan	Malaysia	Russian Fed.	USA	ROW[a]
	Dollars (million)								
Brazil		44	1,027	69	208	5	0	724	797
Canada	187		2,551	122	3,201	57	3	18,053	906
Europe	309	225		214	252	165	385	2,170	58,380
Indonesia	3	31	636		2,059	90	1	471	1,803
Japan	11	19	87	55		92	1	258	1,117
Malaysia	0	9	421	24	1,826		0	143	1,603
Russian Federation	2	4	1,536	4	787	5		70	492
USA	388	3,073	4,050	233	3,752	142	14		4,046
ROW[a]	199	59	2,326	256	3,106	247	56	1,334	

[a] Rest of the World.
Source: United Nations Food and Agricultural Organization (2000).

all of U.S. imports of softwood lumber, panels, and newsprint are from Canada. The United States has negotiated through GATT (now WTO) and other bilateral and multilateral accords some of the lowest barriers to forest products imports in the World. These accords have helped to ensure that U.S. barriers to timber product imports are kept low, probably facilitating the import into this country of wood fiber from emerging producers such as Brazil and Chile. These same accords, however, have also boosted timber product exports to many of those same countries. Recent trade agreements [the Canada-U.S. Free Trade Agreement (CUSTA) and the North American Free Trade Agreement (NAFTA)] have reduced many barriers to trade between these two trading partners, but some disputes have long simmered over softwood lumber and other product exports to the United States. Because the United States is a net timber product importer, then, these lower barriers may have served to reduce returns to timber growing and timber product manufacture in the United States. For example, a growing trend has been the importation of hardwood fiber into the United States from Latin America, especially Brazil. So far, these imports are relatively small, but a possible result of this trend, should it continue, would be to dampen prices below what they would be without such fiber imports. Nevertheless, the trade liberalization agreements, including NAFTA, CUSTA, and WTO-sponsored rounds of barrier reductions, tend to increase aggregate timber product output in the long run and to increase exports of U.S. wood products (e.g., Prestemon and Buongiorno 1996), benefiting American timber producers. The net effects of trade liberalization on the entire U.S. timber-based sector, therefore, are probably small (Barbier 1996, Trømborg and others 2000).

Southern timber products of importance in trade include southern pine (*Pinus* spp.) lumber, hardwood lumber [especially oak (*Quercus* spp.)], southern pine plywood, kraft pulp, and kraft-based paper (packaging and paperboard). The principal destinations for these products are Western Europe, Latin America, and the Caribbean. Because the population and economies of the latter two regions are growing quickly, demand there for southern

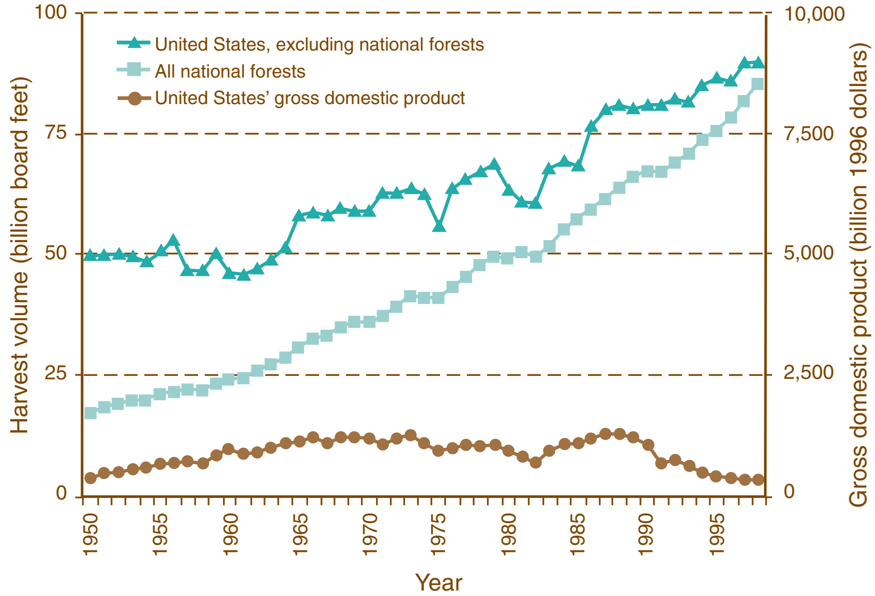

Figure 13.2—Total U.S. harvests, national forest harvests, and U.S. real gross domestic product, 1950 to 1998 {all national forests harvest (cut) volume—U.S. Department of Agriculture, Forest Service (2000); U.S. total harvest volumes—Personal communication. [2000]. Kenneth Skog, Project Leader, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705; U.S. gross domestic product— U.S. Department of Commerce. 2000. [Data]. On file with: Southern Research Station, Forestry Sciences Laboratory, P.O. Box 12254, Research Triangle Park, NC 27709}.

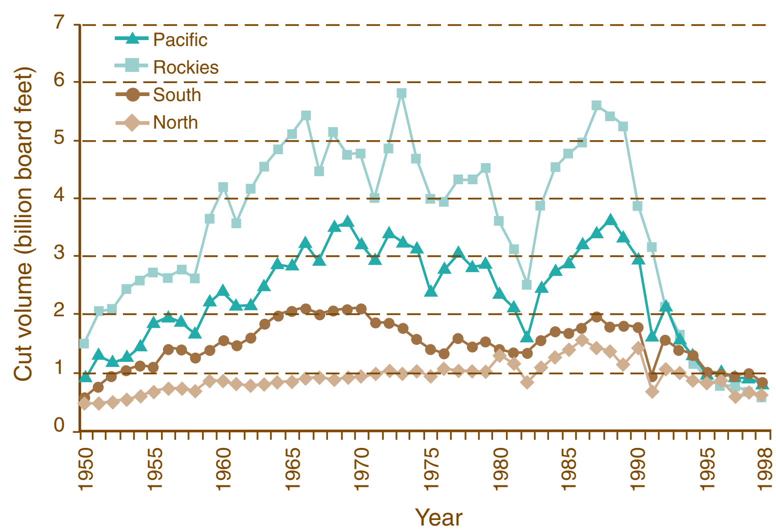

Figure 13.3—National forest harvests by geographical region, 1950 to 1998 [Pacific: national forests in the Pacific Northwest (Region 6), Pacific Southwest (Region 5), and Alaska (Region 10); Rockies: Northern (Region 1), Rocky Mountain (Region 2), Southwestern (Region 3), and Intermountain (Region 4); South: Southern (Region 8); and North: Eastern (Region 9) and former Region 7] (U.S. Department of Agriculture, Forest Service 2000).

timber products exports also can be expected to rise rapidly. Asian countries for the most part have not been major purchasers of southern products (one exception is hardwood chips going primarily to Japan), so the effect of that region's growth in population and wealth, should long-term trends continue, would be to increase timber product prices in the United States and Canada.

United States supply-and-demand history and status—Demand for timber products in the United States has shifted among regions continuously since the 1800s. Settlement in the East, upper Midwest, interior West, and the far West was often preceded and facilitated by harvests of old-growth forests. In the East, virtually all of the forests were harvested in the process of land cover conversion to agriculture, but some forests were allowed to grow back. This process was repeated as European settlement moved westward over the ensuing decades. The final stages of old-growth forest liquidation happened in the Pacific Northwest in the last century; the remaining portion is largely protected by reserves, parks, and government policies adopted in the late 1980s and 1990s.

National forest harvests have changed markedly since 1950 (fig. 13.2). In that year, their share of the U.S. harvests was 6.6 percent. By 1964, it was 17.5 percent. But by 1998, the share had dropped, this time to 3.5 percent, a result of desires to preserve remaining old-growth forests in the West, to protect habitats of endangered species, and to limit clearcutting. Except for the southern region, harvests have declined since 1990 to small fractions of harvests observed in the mid-1980s (fig. 13.3, which excludes the early harvests in tropical national forests). The largest percentage drop in harvests was in the Pacific regions, notably the Pacific Northwest. The Pacific Northwest's share in total U.S. harvests declined from a 1950 to 1989 average of 5.8 percent of all harvests to 0.7 percent of all harvests in 1998.

End uses for harvested wood have evolved over the years, with the mix of uses moving from solid wood outputs, such as lumber, to a greater share of composite products, such as particleboard and paper. As a result, the amount of timber being processed into wood chips, nonwood materials, and recycled fiber has been increasing (fig. 13.4). The increased use of recycled fiber and other fiber and product substitutes shown in figure 13.4 can explain part, but not all, of the decline in timber harvests in the United States since the early 1990s. Another major factor is the steady rise in net product imports. Third has been the increasingly complete utilization of wood in manufacturing processes (fig. 13.5) (Ince 2000), which would compensate for some of the steadily rising demand for timber products that has been observed in recent decades. Wood-use efficiency rose 41 percent from 1952 to 1998. Wood-use efficiency was 9 percent higher in 1998 than in 1990, which can also account for much of the reduction in the observed timber product output of the past few years.

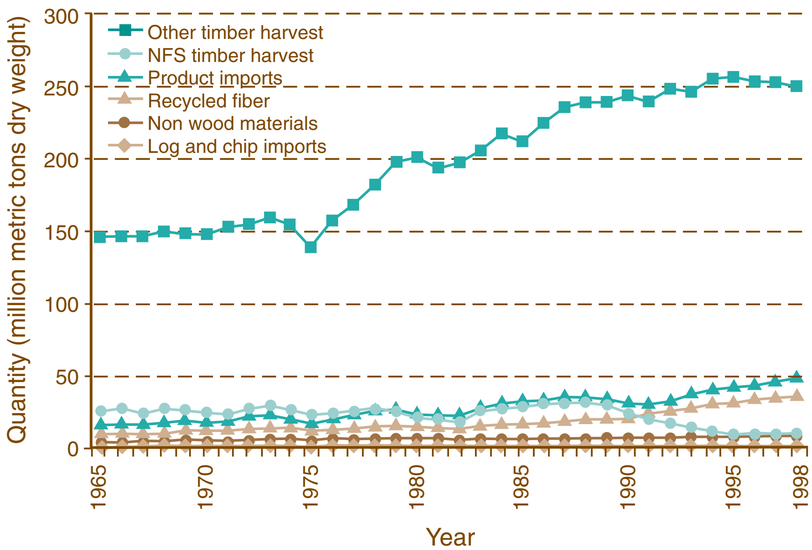

Figure 13.4—U.S. fiber consumption, by source, 1965 to 1998 (Personal communication. [2000]. Kenneth Skog, Project Leader, and Peter Ince, Research Forester, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705).

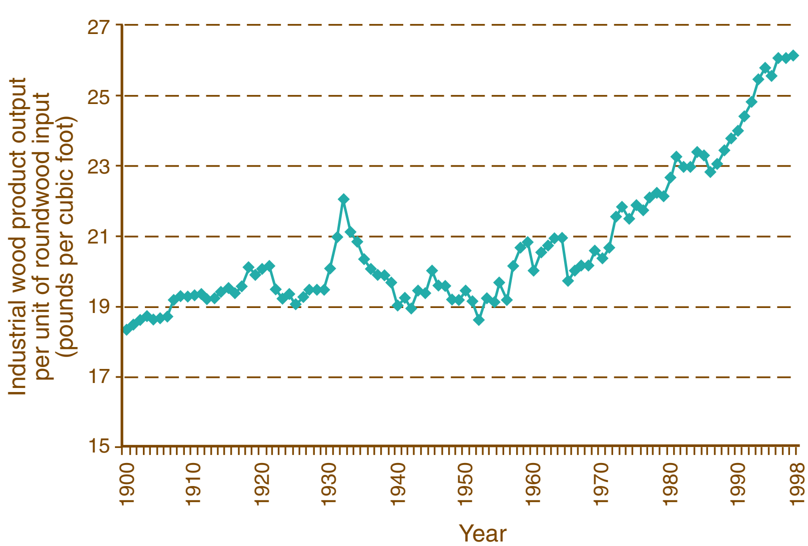

Figure 13.5—Industrial wood productivity in the United States, 1900 to 1998 (Ince 2000).

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Southern supply-and-demand history and status—Southern States produce most of America's industrial wood output, and their share has grown steadily since the 1960s (fig. 13.6). The South produced 41 percent of the country's wood fiber output in 1952 and 58 percent in 1997. Over the same period, the South's share of the World's industrial wood production rose from 6.3 to 15.8 percent. Meanwhile, the Pacific region's share of the country's production dropped from 24.8 to 16 percent.

In terms of timber value, the South's role in production has grown steadily since the 1960s, as well. In other regions of the United States, this share has been somewhat less stable (fig. 13.7). As a result, the timber product sector has been a more dependable source of economic output in the South compared to other regions. The increase in output observed in the South implies that investment opportunities for intensive forest management and product manufacture have improved in the South relative to other regions (Guan and Munn 2000, Murray and Wear 1998).

Over the last 50 years, the relative desirability of western and southern timber products has changed. Earlier in that period, western conifers, which dominated much of the timber product market, were considered ideal in construction framing and sheathing, and in pulp. Spruce (*Picea* spp.), fir (*Abies* spp.), Douglas-fir (*Pseudotsuga menziesii* Franco), western hemlock [*Tsuga heterophylla* (Raf.) Sarg.], and western pines make excellent framing lumber and plywood because of their lightness (low density), strength, stability, and workability. Southern pine, on the other hand, historically was not as desired as western and northern softwoods in construction applications. As timber product manufacturing technology for southern pine advanced, however, southern pine's desirability in national construction markets improved. Until the 1960s, the technology for producing southern pine plywood with desirable characteristics for construction that could compete directly with western plywood did not exist. Similarly, until the 1980s, when old-growth rot-resistant woods such as redwood and western redcedar became scarce and before chemical treating technology for southern pine was perfected, treated southern pine lumber was not as desirable for outdoor applications such as decking. Since then, treated southern pine has supplanted these western woods for much of the outdoor application market.

Western manufacturers of strong, long-fiber pulp and paper rely largely on residues from coniferous wood products manufacture—slabs, shavings, and trimmed edges. Therefore, the softwood sawtimber harvest reductions in the West in the 1980s and 1990s have been accompanied by reduced output of pulpwood. Nationally, pulp and paper manufacturing has become more reliant on sources other than western conifers. Southern pine fibers are ideal for high-strength pulp (especially kraft pulp), so pulp and paper manufacturing has become more dependent on pulpwood production in the South as paper demand has grown and western timber production has waned. The rise in the output and technological advancements in structural and nonstructural wood

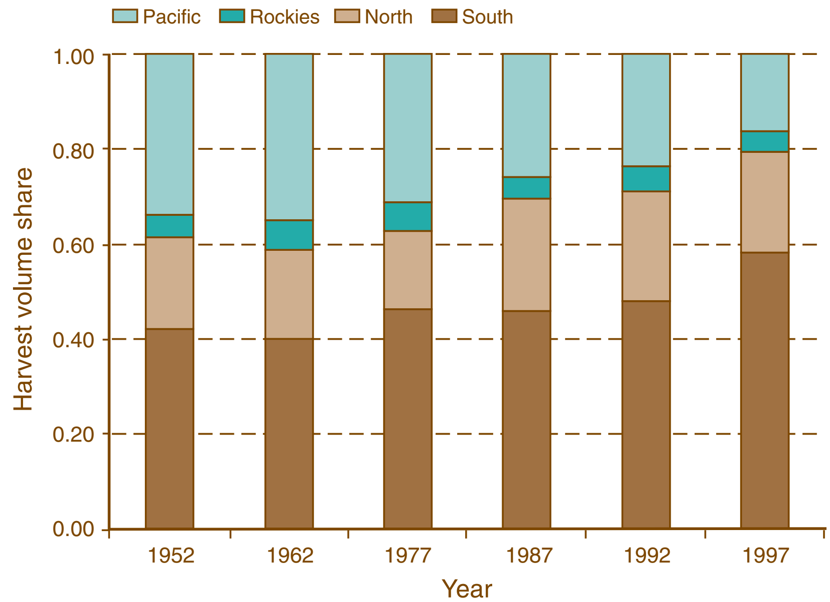

Figure 13.6—Shares of timber harvest volumes, by USDA Forest Service Region of the United States, 1952 to 1997 (Haynes and others 2002).

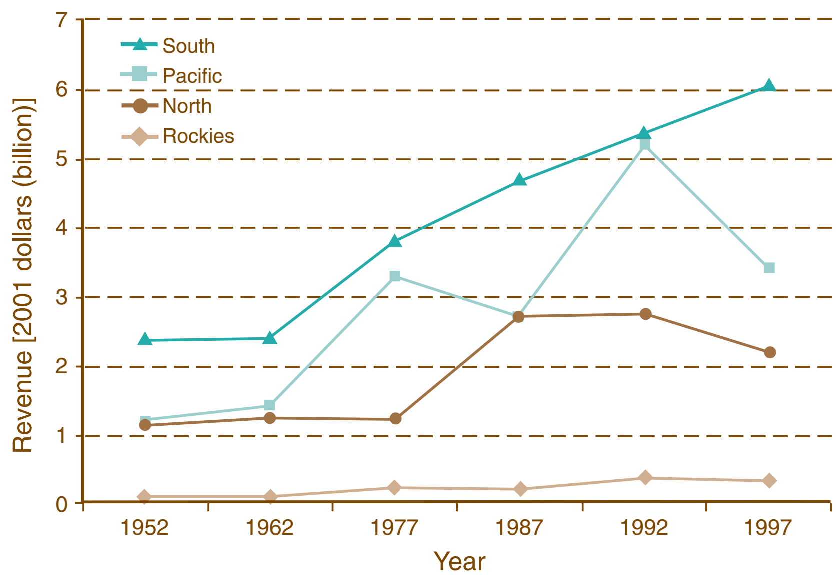

Figure 13.7—Timber harvest revenues, by USDA Forest Service Region of the United States, 1952 to 1997 (Wear, D.N. 2002. [Data]. On file with: Southern Research Station, Forestry Sciences Laboratory, P.O. Box 12254, Research Triangle Park, NC 27709).

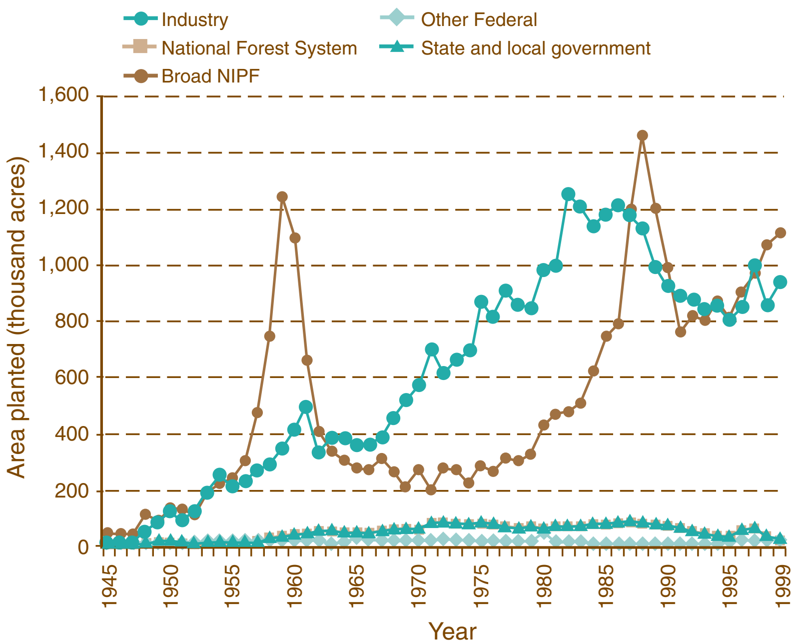

Figure 13.8—Tree planting in the South, by major ownership group, 1945 to 1999 [Robert F. Moulton, compiled from annual USDA Forest Service tree planting reports; including estimates for industry (Arkansas 1954; Florida 1981; Georgia 1954, 1982; Louisiana 1954, 1981; Mississippi 1954; Texas 1981)].

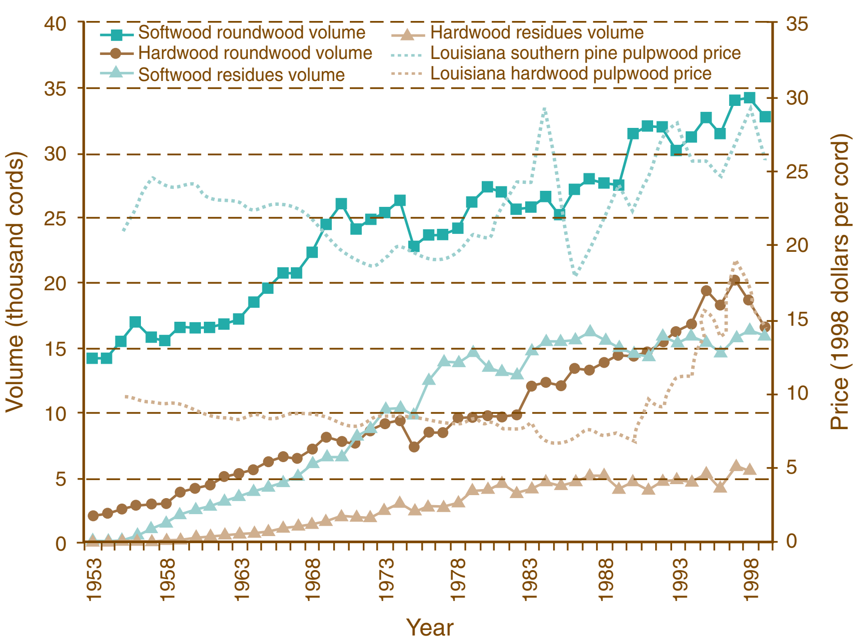

Figure 13.9—Southern pulpwood production, 1953 to 1998, by product class, and Louisiana southern pine and hardwood pulpwood stumpage prices, 1955 to 1998 (Johnson 1996; Johnson and Howell 1996; Johnson and Steppleton 1996, 1997, 1999; Louisiana Department of Agriculture and Forestry 2000).

panels and other engineered wood products has created new demands for smaller diameter and lower quality hardwood and softwood timber.

Without increased investment in the forest sector, production contraction in one part of the country, such as recently observed in the Pacific Northwest, inevitably leads to rising timber prices, rising imports, shifts in demand away from wood-based and toward nonwood product substitutes, and the development of new and more efficient manufacturing technologies. In response to price rises, increases in wood product imports, and product substitutions (fig. 13.4), product manufacturers in the United States, the South, and elsewhere have enhanced wood-use efficiency (fig. 13.5).

Other responses to changing technologies and price increases have been new and rapidly rising rates of investments by landowners in the South in pine growing technology. This technology has two parts: (1) intensive cultivation, including tree planting, thinning, fertilization, and vegetation management; and (2) genetic improvement. An index of southern investments in tree growing technology is the rate of tree planting (fig. 13.8). The trend in such planting has been upward since 1945, with two sharp peaks since that time. The peaks were created in part by incentives programs, including the Soil Bank and Conservation Reserve Programs. Although some of the planting is on newly harvested plantations themselves, part of it is on land previously used for agriculture and part on land previously covered by natural forest types. Both kinds of planting are indicative of how producers have sustained or increased their investments in timber management. The net effect of those investments has been a rising share of pine plantations in the total timberland area in the South.

In spite of rising pulpwood production and improvements in product manufacturing efficiency, producers have not been able to increase output as fast as the economy's demands for pulp-based products have grown. As a result, pulpwood prices (adjusted for inflation) have risen (fig. 13.9). In 1953, virtually no residues (wood chips and other wastes) were used in wood products manufactured in the South; panels and pulp were made from roundwood. By 1998, residues accounted for about 29 percent of the volume of both softwood and hardwood fiber received at the gates of pulp mills and composite panel mills (Johnson and Steppleton 2000, p. 9). Given the price rise along with the production increase, it is apparent that technological change and the economic advantages provided by the technology have not been enough to keep prices from rising in real terms. Still, these steadily rising prices serve as incentives for consumers of pulpwood and producers of pulpwood to invest in efficiency-enhancing technologies.

Another important trend that has arisen out of changing technologies and increasing prices has been the rising share of hardwood in southern timber production. For example, in 1953, hardwood roundwood was about 12 percent of all roundwood removed, while in 1999, hardwood roundwood was 34 percent. Hardwood roundwood nearly tripled in output while softwood roundwood slightly more than doubled. Price changes reflect this: hardwood roundwood prices have increased by two-thirds in real terms over the period, while softwood prices have increased by about 15 percent.

Another way that producers of timber products in the South have adapted to rising demands, increasingly competitive substitute products and imports, and rising prices is by altering timber processing. One change in recent years is the chipping of wood at satellite locations. This process is controversial because it encourages

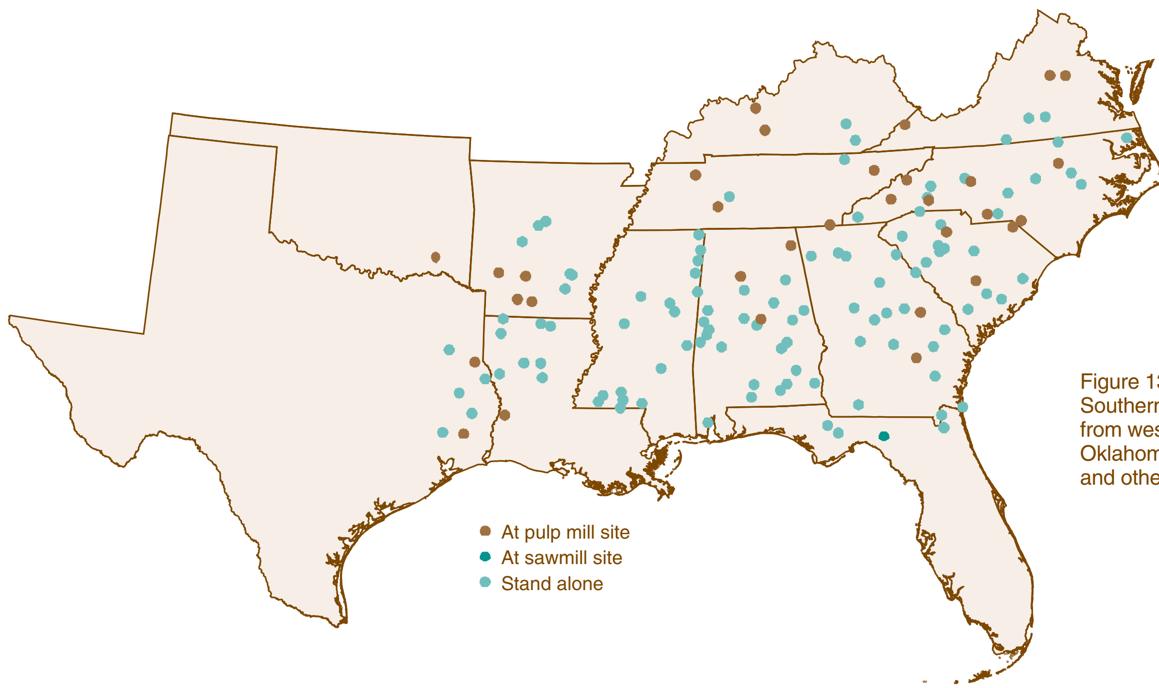

Figure 13.10—Chip mills in the Southern United States (no mills from western regions of Texas or Oklahoma are shown) (Prestemon and others 2001b).

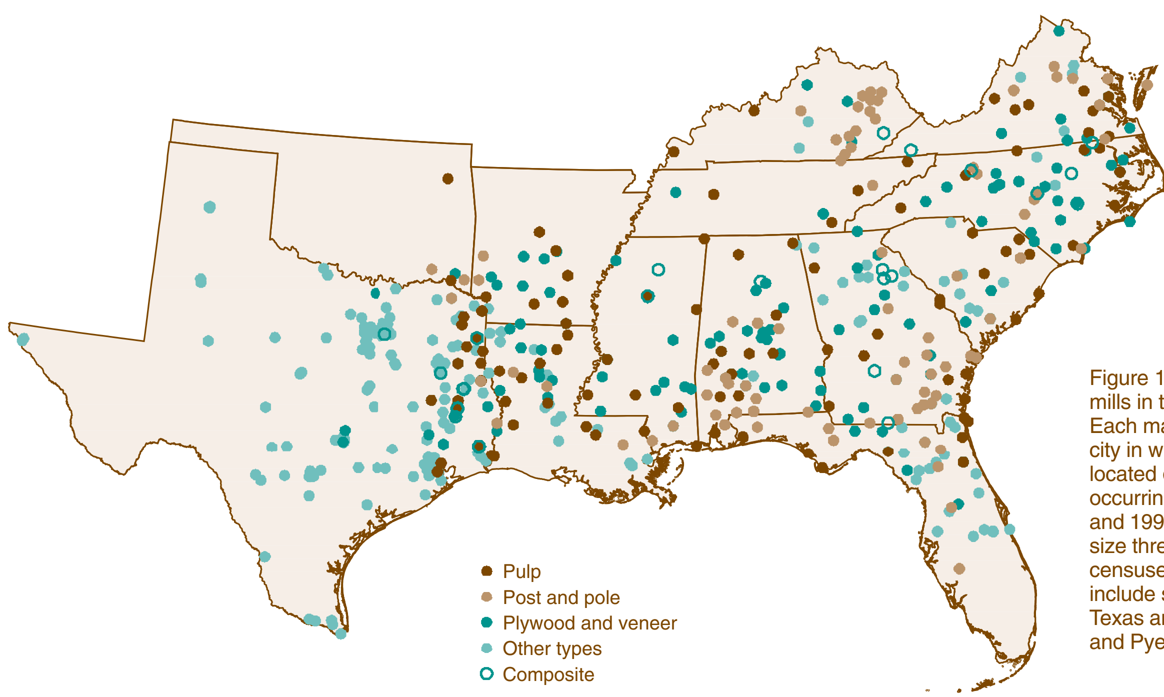

Figure 13.11—Other wood-using mills in the Southern United States. Each mark indicates a town or city in which at least one mill was located during mill censuses occurring between 1992 (Virginia) and 1997 (Texas). Minimum mill size thresholds for inclusion in the censuses varied by State. The data include such qualifying mills in all of Texas and Oklahoma (Prestemon and Pye 1999).

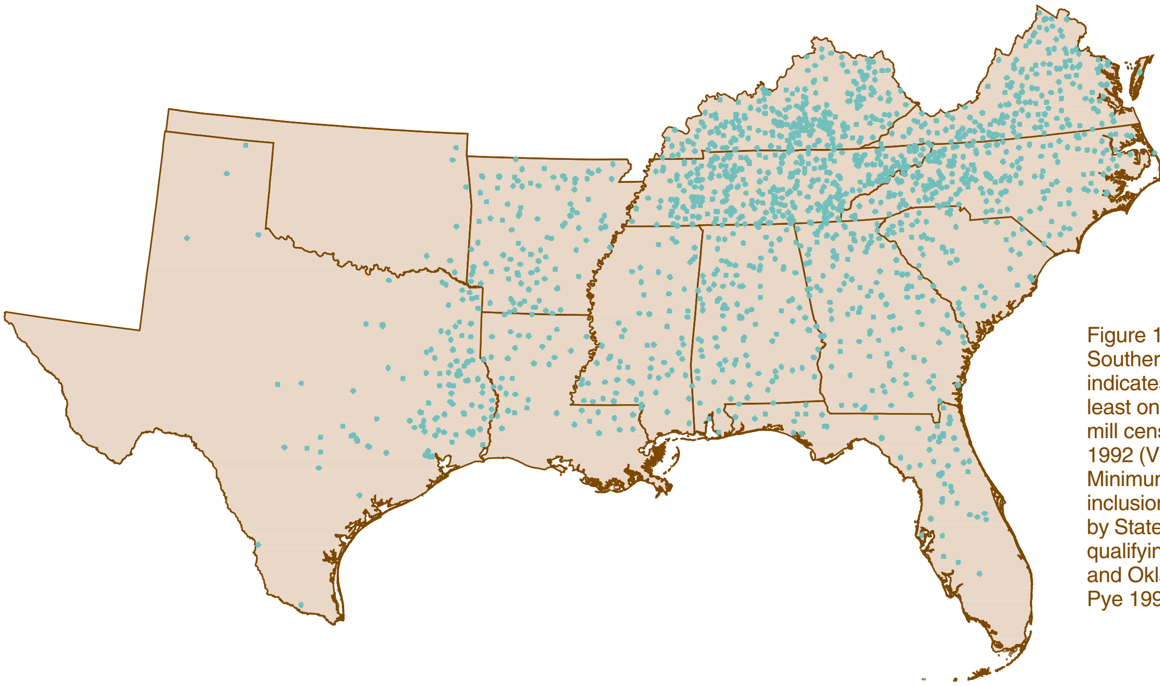

Figure 13.12—Sawmills in the Southern United States. Each mark indicates a town or city in which at least one mill was located during mill censuses occurring between 1992 (Virginia) and 1997 (Texas). Minimum mill size thresholds for inclusion in the censuses varied by State. The data include such qualifying mills in all of Texas and Oklahoma (Prestemon and Pye 1999).

harvesting in areas not previously subject to harvesting and encourages clearcutting, especially of natural management types that before were harvested in a different way. Many view this as negative. Others have viewed the technology positively, creating conditions for better forest management because the chipping technology discourages incomplete or high-graded harvests and because it provides additional income to owners of lower quality timber. Before the 1990s, pulp mills and manufactured wood panel mills relied heavily on remote log concentration yards and maintained large chipping facilities at the site of panel and pulp manufacture. Today pulpwood-sized logs increasingly are chipped away from the mill and are brought to the mill as needed. Per unit of volume, moving wood in chipped form is cheaper than moving pulp logs (Dodrill and Cubbage 2000), providing a significant economic benefit to pulpwood consumers and log producers. The current distribution of these remote or stand-alone chip mills is shown with the locations of other kinds of chipping facilities in figure 13.10. The buyers of most of these chips, pulp mills and manufactured panel mills, are shown along with miscellaneous other mills in figure 13.11. A small portion of these chips also derives from a few of the thousands of southern sawmills (fig. 13.12). Note that the remainder of the material used by pulp mills is processed as chips onsite at pulp mills and panel mills, arriving there as roundwood. See figure 13.10 for the locations of those pulp mills and panel mills.

The majority of chips produced in the South are used to make paper and composite wood panels. In 1998, there were 159 chip mills (Prestemon and others 2001a), but by 2000, 146 were found in the South (Prestemon and others 2001b). More than three-fourths of all chip mills were stand-alone in 2000, not directly tied to a particular wood processing plant; most of the remainder were tied to a pulp mill. Chip mills processed about 27 percent of the pulpwood in the South in 1999 (Hyldahl and others 2000). They produced 47 million green tons of chips in 1998, 45 million green tons in 1999, and 39 million green tons in 2000. In 1999, approximately 42 percent was softwood and 58 percent was hardwood.

Not all of the wood chips produced in the South are consumed by U.S. mills (fig. 13.13). Since 1989, increasing amounts of wood chips have been

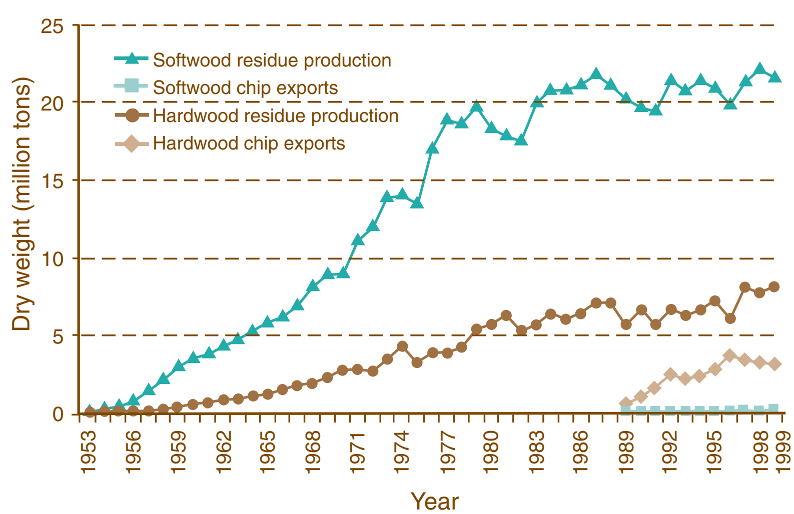

Figure 13.13—Southern wood chip residue production (1953 to 1999) and wood chip exports from southern customs districts (1989 to 1999), softwood and hardwood (Hansen and Hyldahl 2001; Johnson 1996; Johnson and Steppleton 1996, 1999, 2001).

exported from the United States. Between 1989 and 1999, residue exports from southern ports increased 369 percent for hardwood and 372 percent for softwood. Because most residues today are in the form of wood chips, we can say that the export share of southern hardwood residue production increased from 12 percent in 1989 to 39 percent in 1999, while the export share of southern softwood residue production increased from 0.3 to 1.3 percent between those years (U.S. Department of Commerce. 2000. [Data]. On file with: Southern Research Station, Forestry Sciences Laboratory, P.O. Box 12254, Research Triangle Park, NC 27709). Hardwood and softwood wood residue production comprised approximately 12 percent of all wood fiber production in the South in 1996, the latest year for which data are available.

Another indicator of the effect of changing wood production and manufacturing technology is the rising importance of more highly manufactured timber products. Apparently there is a trend toward concentrating a higher proportion of value added at the point of initial manufacturing. Since the 1950s, the use of wood for fuel, posts, poles, and pilings has declined, in favor of wood produced for lumber, paper, and engineered wood products (fig. 13.14). The proportion of output going to fuel wood in the 1950s was over 20 percent; it has since dropped to under 3 percent. The share of output dedicated to the category of other product removals—primarily for posts, poles, pilings, and composite products—has fallen by two-thirds, settling today at about 2.5 percent of timber product output in the South. Between 1954 and 1996, the percentage of wood removed as saw logs was nearly constant, at around 38 percent. Pulpwood's share rose from 21 percent in 1952 to 47 percent in 1972 and has since leveled off at around 40 percent. The proportion of output in the form of the largest and highest quality logs, veneer logs, has trended upward, from 3 percent in 1952 to about 9 percent in the 1990s. Hence, in contrast to the trend toward more wood products derived from pulpwood, which doubled in importance between 1954 and 1996, the importance of sawmills, especially those manufacturing hardwood lumber and veneer, has remained constant. In the South, the largest number of hardwood sawmills is in areas where hardwood production is most dominant: mountainous portions of Virginia, North Carolina, and Tennessee (fig. 13.12). But overall production of hardwood timber is highest in Mississippi, North Carolina, Georgia, Alabama, and Virginia.

Projections of Supply and Demand

Supplies of and demands for timber products in the South will depend heavily on national and World trends. Southern supplies and demands through 2040 were projected with the SRTS model, with national and international trends taken as given. What follows is a discussion of some of the World and national projections from the literature plus a description of how SRTS projects what will happen in the South in the coming decades.

World supply-and-demand projections—World timber production is expected to rise steadily well into the 21st century. Projections by Trømborg and others (2000) show that timber production will increase by 1.2 percent per year through 2010, with likely continued increases beyond that year. Their analysis also projects: (1) that U.S. growth in production will be 0.4 percent, implying that the United States will remain a timber product importer; (2) that the U.S. share of exports on World markets may decline; and (3) that U.S. imports will rise. The United States experienced an average compound annual growth rate for timber products output of 1.4 percent from 1961 to 1999, so this lower rate of 0.4 percent appears to be a substantial departure from the past but closer to the realized compound annual growth rate since 1990, which has been essentially nil (0.04 percent).

United States supply-and-demand projections: RPA—The Draft Forest and Rangeland RPA assessment (Haynes and others 2002) projects that the character and location of timber and timber products output will change over the coming half-century while timber product prices and land and timberland area will decline by 3 percent. The Draft 2000 RPA projects in its base projection that the area of forestland is expected to decline by 3.6 million acres in the South and to decline by 19.6 million acres elsewhere.

The Draft 2000 RPA assessment base projection also projects that privately owned forests in the United States will be more intensively managed, partly as a response to declining forest area. It also projects that private forests will be expected to produce an increasing share of small-diameter materials for pulp and composite wood products. Timber production overall is projected to continue its shift toward the South, which contains a large share of the Nation's private forests and timberland. Domestic consumption of softwoods is projected to increase in the base projection by 47 percent and hardwoods by 29 percent between

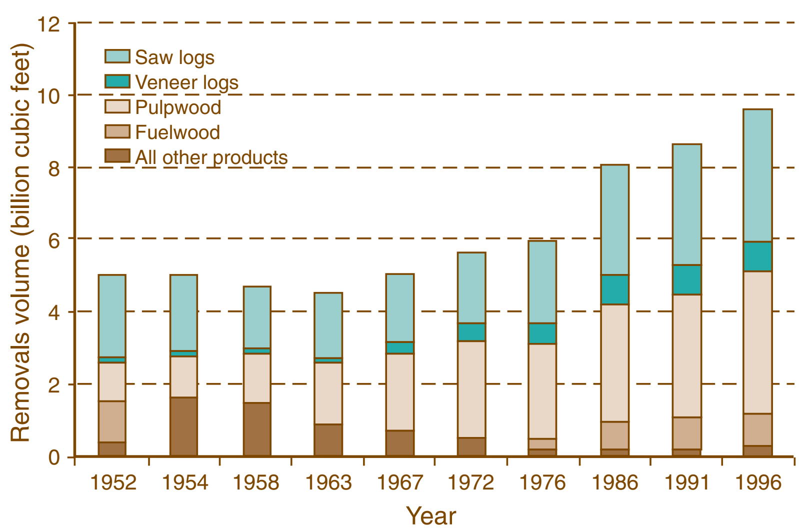

Figure 13.14—Removals by destination product, Southwide, all species, 1952 to 1996 (data for 1954 to 1972 all other products include fuelwood) [Hair (1963, p. 32-33); Haynes and others (2002); Phelps (1980, p. 31); Powell and others (1994, p. 36); U.S. Department of Agriculture Forest Service (1958, p. 570, 641-642; 1982, p. 422); Waddell and others (1989, p. 89)].

1996 and 2050, while harvests are projected to increase 30 percent for softwoods and 17 percent for hardwoods between 1996 and 2050. Per capita consumption of roundwood, however, is projected to remain fairly stable, at 0.8 tons per capita per year.

The shares of outputs going into various solid wood products are projected by RPA to change over the next half-century, much of that driven by evolving technologies that result in rising technical efficiencies. Composite wood structural panels are projected to partially displace plywood, while softwood lumber shares are projected to grow relative to hardwood lumber. Imports from Canada and elsewhere are projected to rise, especially in the short term. Softwood lumber, pulp, paper, and paperboard production are projected to increase most in the South, especially in the western portion of the region. Although manufacturing efficiency (units of output per unit of wood input) is projected to continue to increase, the rate of that increase is projected to slow, relative to that experienced in the 1900s. Between 2000 and 2050, the output:input ratio is projected to rise by 16 percent.

Hardwood and softwood timber harvests are projected to increase similarly, by over one-third, over the coming half-century. This rise will be made possible by improvements in timber growing technology, especially intensification through plantation management, fertilization, thinning, and genetic improvement.

The Nation's softwood timber harvests are projected to continue to come mostly from the South, rising from 61 percent of U.S. timber harvests in 1997 to 65 percent by 2050 (Haynes and others 2001). The shares of softwood provided by the other regions of the country are projected to be steady or to decline over the coming 50 years. In hardwood, production in the Rocky Mountain West and Pacific Coast is expected to rise but remain small, while the Northern United States is projected to rise slightly in importance while the South declines slightly in importance. Nevertheless, the South and North are both projected to increase their hardwood outputs. By 2050, the South is projected to provide 50 percent of hardwood roundwood harvests and the North 44 per cent. In total, the South's share rises only slightly, by less than 1 percent by 2050 compared to its 58-percent share of harvests in 1997. To a large extent, the high and rising productivity and area of southern pine plantations makes the rise in the southern share of softwood harvests possible.

The RPA assessment projects that the United States will increase its dependence on foreign sources of wood fiber (logs, lumber, panels, residues, pulp, waste paper, etc.) as a proportion of total consumption. The projection shows imports providing 27 percent of wood fiber consumed in 2050, compared to 20 percent in 2000. These findings are consistent with the shorter run projections of Trømborg and others (2000), which show that the value of U.S. net exports (exports minus imports) will become more negative by 2010.

An effect of greater investment in manufacturing technology and rising fiber demand is a projected relative rise in the importance of recycled fiber in the paper sector. Use of recycled fiber has been increasing and will continue to do so (Ince 2000). Over the 50-year RPA projection, recycled fiber use is projected to more than double, while wood fiber from timber harvests is projected to increase by 40 percent.

Timber prices in the United States are projected by RPA to change differentially, depending on product and species. Timber prices for softwood sawtimber are projected to rise over the projection in all regions of the United States by between 13 and 69 percent (39 percent in the South), while softwood pulpwood prices are projected to rise in the North and fall (by 29 percent) in the South. In hardwood, sawtimber prices are projected to rise slightly in the North and more than double in the South. Hardwood pulpwood is projected to nearly double in price in the South and decline in the North.

Southern supply, demand, management intensity, and land use projections: SRTS—We used the 2000 RPA projections to provide national and global context, but we made projections for the South independently from RPA projections. SRTS projections of forest area, harvests (removals), growth, and inventory were done under all scenarios outlined in table 13.1 and described in Methods in this chapter. Starting-point data on inventory, net growth, and removals used in the SRTS projections were obtained from the latest FIA data available for download from the FIA Web site. Projection data for States with relatively old surveys could be misrepresented if growth, removals, or land use changes including tree planting (fig. 13.8) have changed greatly between the survey and 1995. These problems may exist for projections of South Carolina (due to Hurricane Hugo's effects on subsequent growth rate of trees in natural stands) as well as Alabama, Kentucky, Louisiana, North Carolina, Texas, and Virginia.

Area projections for private timberland under the IH (base case) scenario for FIA survey units show the South losing private timberland over the coming decades. This loss, amounting to 1 percent over the 1995 through 2040 projection, is net of an aggregate increase in the area of pine plantations and an aggregate decrease in the area of other forest types (fig. 13.15). A detailed map of forest area changes (fig. 13.16) shows that private timberland area is projected to increase in the western parts of the South, while losses are projected in States along the southern Atlantic seaboard. The gains in private timberland area, facilitated by rising timber prices relative to agricultural rents, will be concentrated in Alabama, Arkansas, Louisiana, and Mississippi. Significant percentage losses are projected for Florida, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Within States, losses are projected to be concentrated near urban areas, while some rural locations gain. This is not universally true, however. For example, all of Florida and South Carolina's FIA survey units are projected to lose private timberland. The South's population and State economies have grown quickly and are projected to continue to grow quickly. With such growth, the demand for land near the urban areas has been, and is projected to continue to be, met by some clearing of forests. Under the IL (fig. 13.15B), EH (fig. 13.15C), and EL (fig. 13.15D) scenarios, aggregate timberland area in the South is projected to change as well. What all of the figures 13.15A (IH), 13.15B (IL), 13.15C (EH), and 13.15D (EL) show is that the area of natural forest management types (all types except pine plantations) is projected to shrink, while the planted pine type increases. This trend would

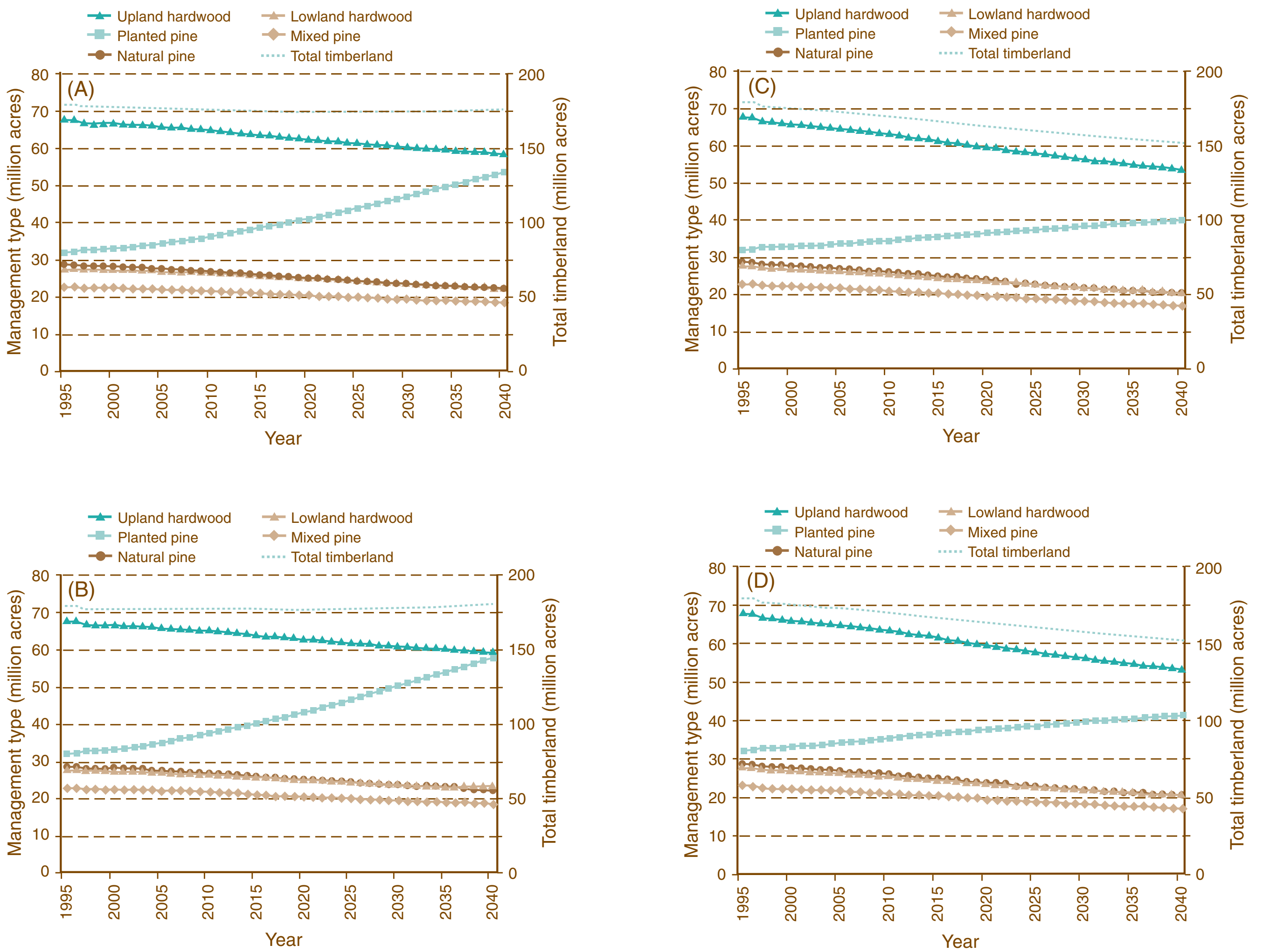

Figure 13.15—Subregional Timber Supply Model projections of private timberland area by management type, 1995 to 2040, under four assumptions: (A) IH or base case—inelastic timber demand and high plantation volume growth rates, (B) IL—inelastic timber demand and low plantation volume growth rates, (C) EH—elastic timber demand and high plantation volume growth rates, and (D) EL—elastic timber demand and low plantation volume growth rates.

appear to be a continuation of that observed over the last 40 years, when little net forest loss was registered but plantation area increased substantially (chapter 16, fig. 16.12).

Common to the IH and IL scenarios, pine plantation areas are projected to increase by 21 to 26 million acres, or by about 67 to 80 percent from 1995 levels of pine plantations. The pine plantation projections by scenario are displayed together, along with historical amounts, in figure 13.17. Increases in pine plantation acres differ among the scenarios considered. These projected increases are similar to the projected acreage of aggregate losses of the natural forest management types under private ownership, keeping private timberland area largely unchanged over the projection, 1995 to 2040. Common to the EH and EL scenarios, however, is that pine plantation area is projected to increase by about 25 percent, insufficient to completely outweigh natural forest-type losses, translating into a net loss in private timberland area of just over 27 million acres (15 percent) between 1995 and 2040. These lower plantation acres are generated because prices, to which pine planting positively responds, do not increase as much under the elastic demand scenarios.

Apparent in the IH (base case) and IL scenarios is that pine plantation area is increasing at the expense of private timberland in other forest types, but this tradeoff is only partial. As pointed out in chapter 16, during the 1980s and 1990s, about 30 percent of new pine plantation acres in the South derived from agricultural land, while around 70 percent came from conversion of natural forest management types. Further, part of the loss of natural forest has historically been, and is projected to be, due to conversions to urban uses (see chapter 6 for details). Similarly, in the IH and IL projections, a share of the private pine plantation acreage increase is projected to be at the expense of agricultural land as well as private timberland that is currently in natural forest management types. In practice, this means that Gulf Coast States and the Coastal and Piedmont regions of Atlantic Coast States will gain the most pine plantations, while northern and interior regions will gain the least plantation area.

A notable direct tradeoff, however, exists when comparing the plantation pine and natural forest management type projections done by the IH (base case) and IL scenarios. In the IL scenario, softwood prices are projected to rise at a faster rate than they are for the IH scenario; the higher prices in the IL scenario serve as the economic stimulus to landowners to plant even more trees. The difference between the IH and IL pine plantation rates yields the marginal effect of higher plantation growth rates on the area of private pine plantations and the area of timberland in private natural forest types projected for 2040. In the IH scenario, pine plantations are projected to cover 53.6 million acres in 2040, while in the IL scenario the figure is 57.9 million acres. Each percentage point increase in growth rate above a 50-percent increase for industry [and each 0.5 percentage point increase above 25 percent for nonindustrial private forests (NIPF)] results in about 170,000 fewer acres of projected pine plantations by 2040. Similarly, because the IH scenario projects private timberland area in natural forest management types of 122 million acres and the IL projects that area to be 123 million acres, each percentage point (for industry and 0.5 percent for NIPF) increase in pine plantation growth rate is projected to save about 50,000 acres of natural forest. Alternatively, if timber demand is elastically responsive to timber price, as laid out in the EH and EL scenarios, the effects of pine plantation growth rate changes on areas by management type are very small.

Figure 13.18 details the changes by State in pine plantation area projected in the IH (base case) scenario. Pine plantation area changes vary among Southern States mostly due to differences among States in the area of industry-owned forests, the amount

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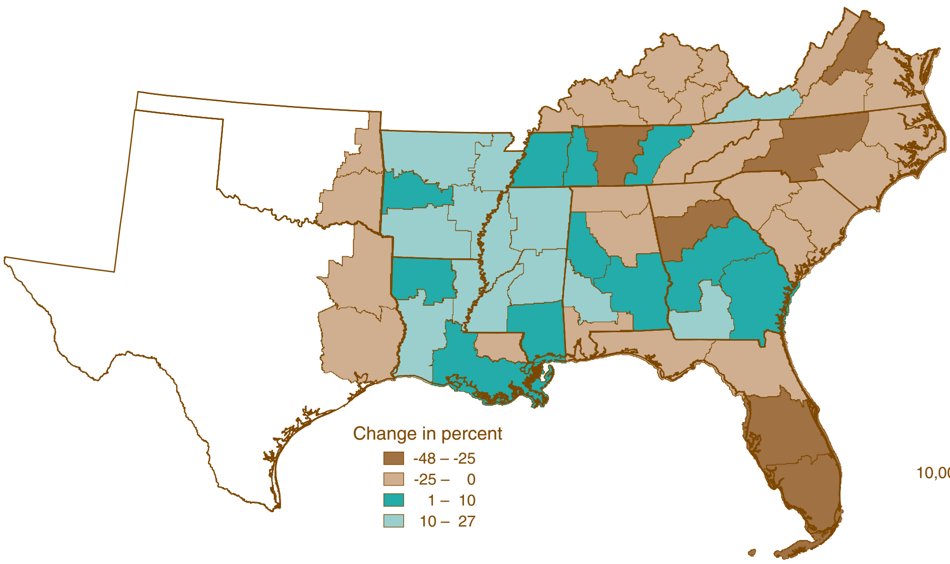


Figure 13.16—Subregional Timber Supply Model projections by USDA Forest Service, Southern Research Station, Forest Inventory and Analysis survey unit of percent change in private timberland area, 1995 to 2040, under assumptions of inelastic timber demand and high plantation volume growth rates.

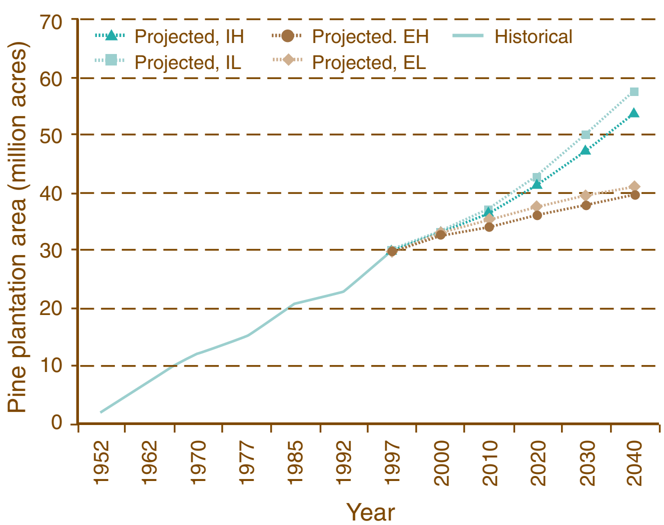


Figure 13.17—Pine plantation area projections by scenario, and historical pine plantation area on private land in the South, 1952 to 2040.

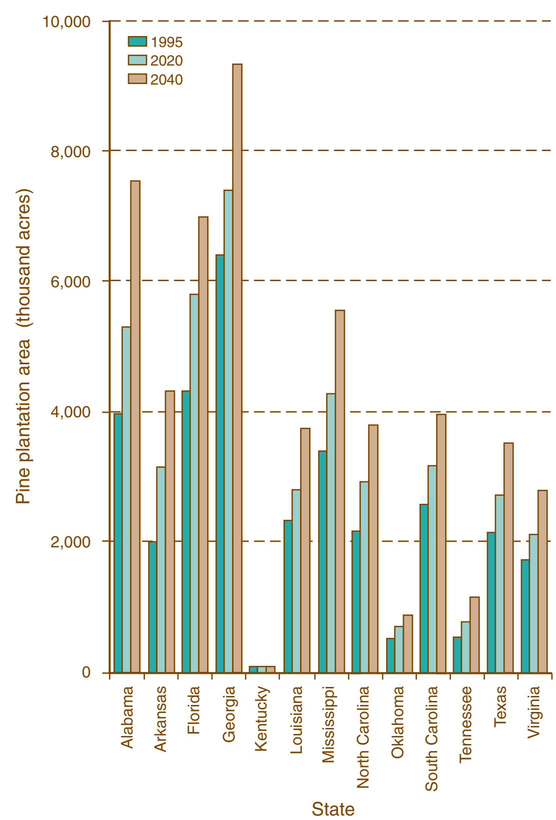


Figure 13.18—Pine plantation area by State on private land in the South for 1995, 2020, and 2040, as projected by the Subregional Timber Supply Model, under the IH (base case) scenario, with inelastic demand and a high pine plantation growth rate increase.

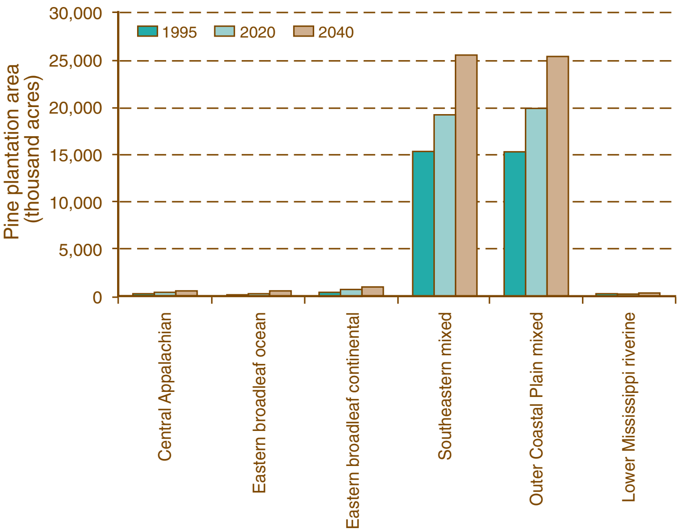


Figure 13.19—Pine plantation area on private land by ecoregion, 1995, 2020, and 2040, as projected by the Subregional Timber Supply Model, under the IH (base case) scenario, with inelastic demand and a high pine plantation growth rate increase.

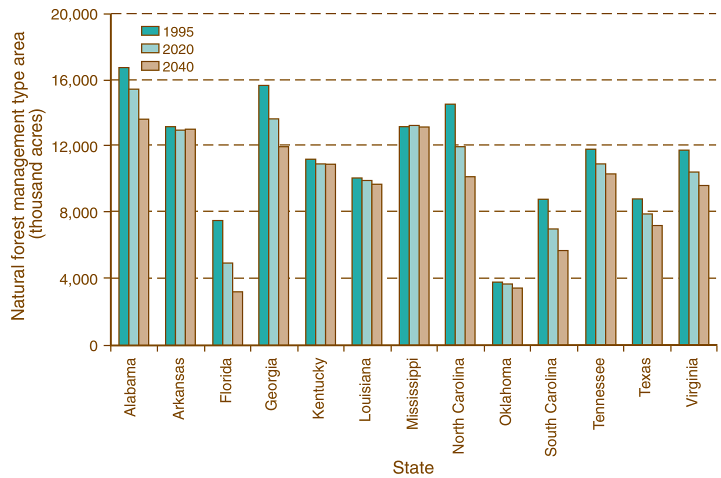


Figure 13.20—Natural forest management type (natural pine, oak-pine, upland hardwood, and bottomland hardwood) area on private timberland by Southern State for 1995, 2020, and 2040, as projected by the Subregional Timber Supply Model, under the IH (base case) scenario, with inelastic demand and a high pine plantation growth rate increase.

of natural pine forests relative to other types (natural pine stands are converted more frequently to plantations), and land use changes to and from nonforest. The amounts of these plantations projected in the base case scenario vary by State and trend upward. All States except Kentucky are projected to gain at least 45 percent in pine plantation area by 2040 compared to 1995, with the largest percentage gains in Tennessee (120 percent), Arkansas (117 percent), and Alabama (89 percent). Georgia, the State with the most pine plantations in 1995 (6.4 million acres), is projected to have the most in 2040 (9.3 million acres). Alabama, with the second most in 1995 (4.0 million acres), is projected to have the second most (7.5 million acres) in 2040.

Under the base case scenario, the increase in pine plantation area is projected to be largest on the Gulf and Atlantic Coastal Plain and Piedmont ecoregions (fig. 13.19). In 1995, the southeastern mixed forest and the outer Coastal Plain mixed forest each contained about 15.4 million acres of pine plantations. They are projected to have 25.6 and 25.4 million acres, respectively, in 2040. The eastern broadleaf forest ecoregions together accounted for about 0.6 million acres of pine plantations in 1995 and are projected

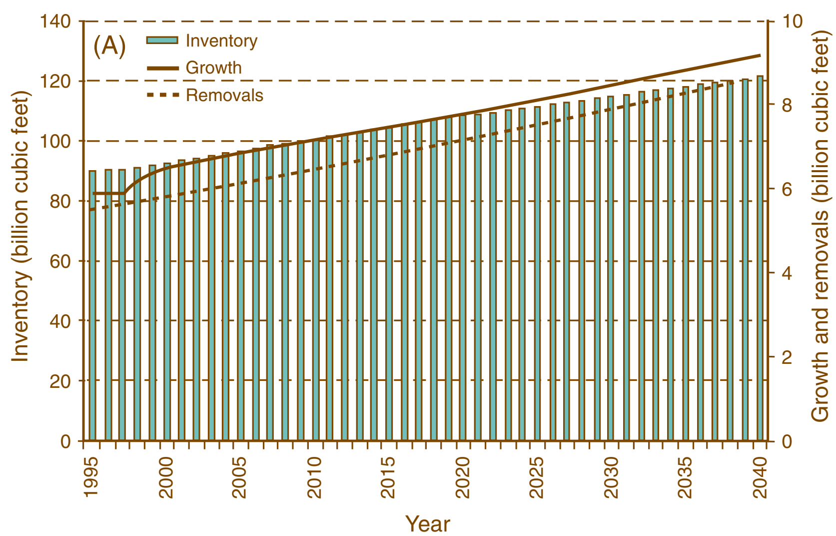
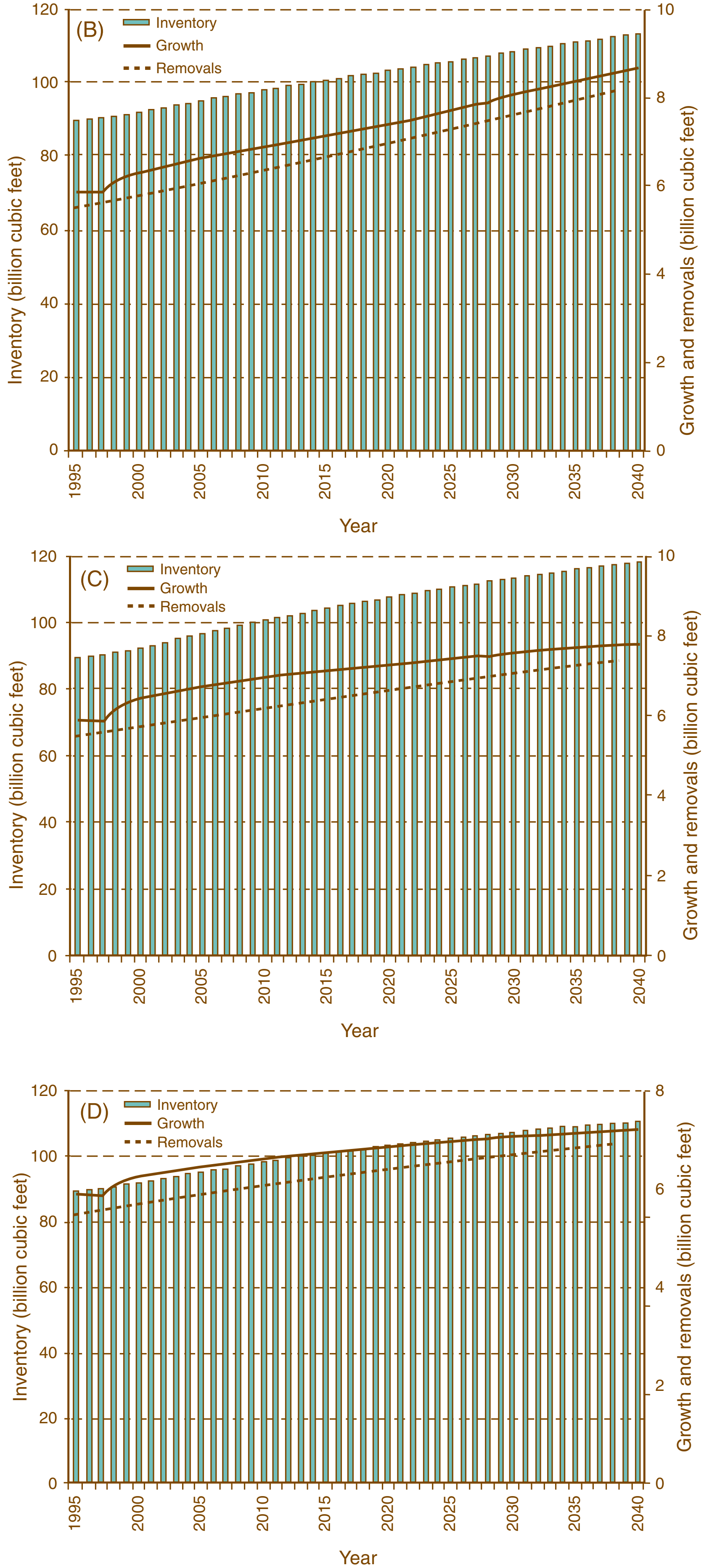


Figure 13.21—Subregional Timber Supply Model projections of softwood timber growth and removals volumes on private timberland in the South, 1995 to 2040, under the IH (base case) (A) assumptions of inelastic timber demand and high plantation volume growth rates, IL (B) assumptions of inelastic timber demand and low plantation volume growth rates, EH (C) assumptions of elastic timber demand and high plantation volume growth rates, and EL (D) assumptions of elastic timber demand and low plantation volume growth rates.



to contain a total of 1.2 million acres of such plantations in 2040.

State-level projected changes in private timberland area in natural forest management types under the base case scenario are shown in figure 13.20. All States are projected to lose acreage in natural forest types under this scenario. States projected to lose most privately owned natural forest types between 1995 and 2040 under this scenario are Florida (58 percent), South Carolina (35 percent), and North Carolina (30 percent). These losses can be ascribed to a combination of pine plantation expansion and a loss of forests to residential and urban uses. In other scenarios, the losses projected for natural forest management types in those States are of similar sizes, and those same States are projected to lose most. Arkansas, Louisiana, and Mississippi are projected in other scenarios to either gain no natural forest management type acres or to lose some (up to 14 percent by 2040 for Arkansas, compared to 1995 levels).

An effect of the projected increase in timberland area in planted pine under the base case and the IL scenarios is a rise in timber inventories. Under the base case scenario, softwood growth is projected to exceed removals during the entire 40-year period (fig. 13.21A). This finding holds for the IL (fig. 13.21B), EH (fig. 13.21C), and EL (fig. 13.21D) scenarios, as well. In the 1990s, in many parts of the South, softwood removals slightly exceeded growth. The projections shown here reflect a turnaround in this situation, although for some States this may take another two decades. (We note here, however, that the FIA surveys upon which 1990s harvest levels were estimated were old, deriving from FIA surveys of the 1980s and early 1990s. Hence, differences between the projected levels of private timber harvests from timberland between 1995 and today may represent the result of the inaccuracies generated from old surveys.) The turnaround is attributable to large investments in pine plantations that are growing faster than they are being harvested. Under the base case scenario, softwood harvests are projected to increase most in percentage terms in the northern reaches of the South (Kentucky, Tennessee, Arkansas, and Oklahoma) and least in southeastern parts (fig. 13.22A). In absolute terms (volume per year), the story is more mixed (fig. 13.22B). Large volume increases are projected in some places that have always been major producing regions (Georgia, Alabama, and Louisiana) and in some that have not (parts of the Piedmont and mountains of North Carolina and Virginia, central Tennessee, and the Ozarks of Arkansas). Even parts of the South projected to lose forest area will have rises in softwood harvests. This is made possible not only by rising growth rates on plantations but also because some forest that is projected to be converted to nonforest uses provides volume that enters timber markets at the time of conversion; the Piedmont and Florida are examples of this. Other places are projected to have decreases in harvests even while forest areas might be stable to rising (parts of Mississippi, Arkansas, and Louisiana). Opposite trends in parts of Louisiana, Arkansas, and Mississippi are mainly attributable to timing: many of the new acres of pine plantations projected in those areas would not be harvested until after 2040.

In aggregate, softwood harvests from private lands are projected to increase by 56 percent between 1995 and 2040 under the base case scenario. This increase is made possible by the combination of the increase in the area of pine plantations and the projected rise in productivity of those plantations. Nearly half of all southern timber volume growth today occurs in pine

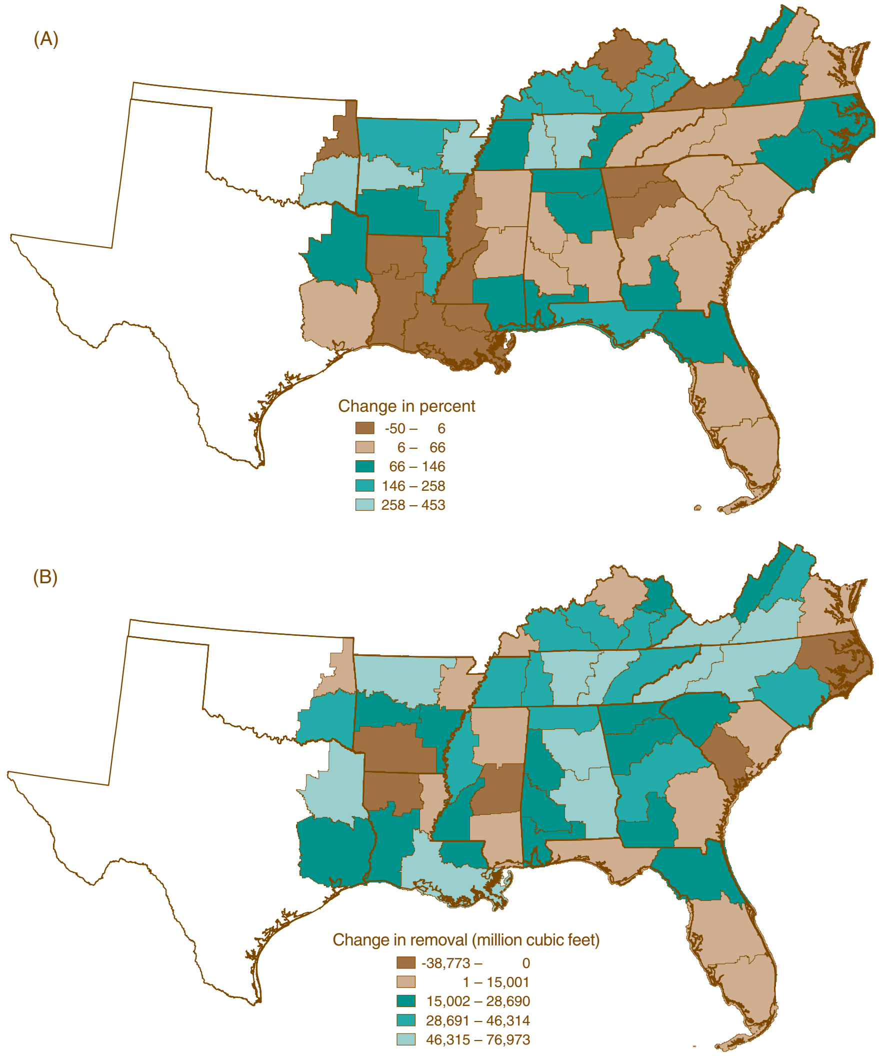


Figure 13.22—Percentage (A) and absolute (B) changes in annual softwood harvest levels from private timberland in the South, 1995 to 2040, as projected by the Subregional Timber Supply Model, by USDA Forest Service, Southern Research Station, Forest Inventory and Analysis survey unit, under the IH (base case) assumptions of inelastic timber demand and high plantation volume growth rates.

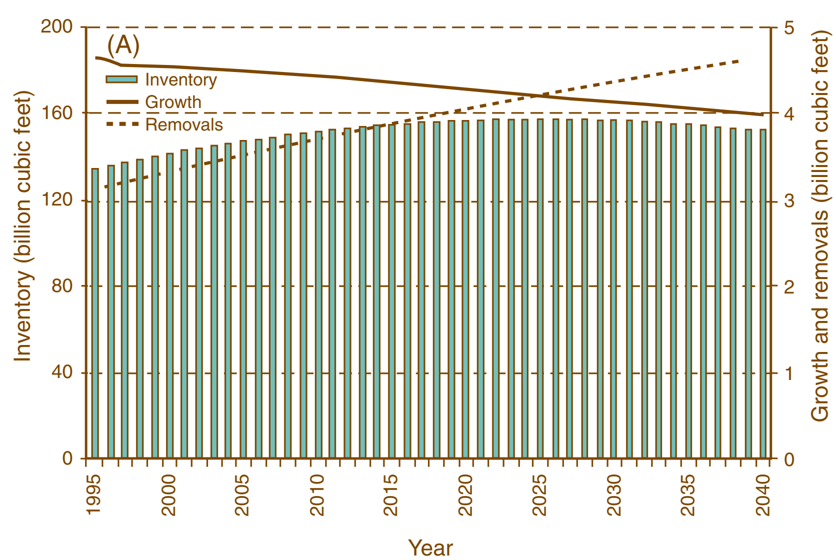
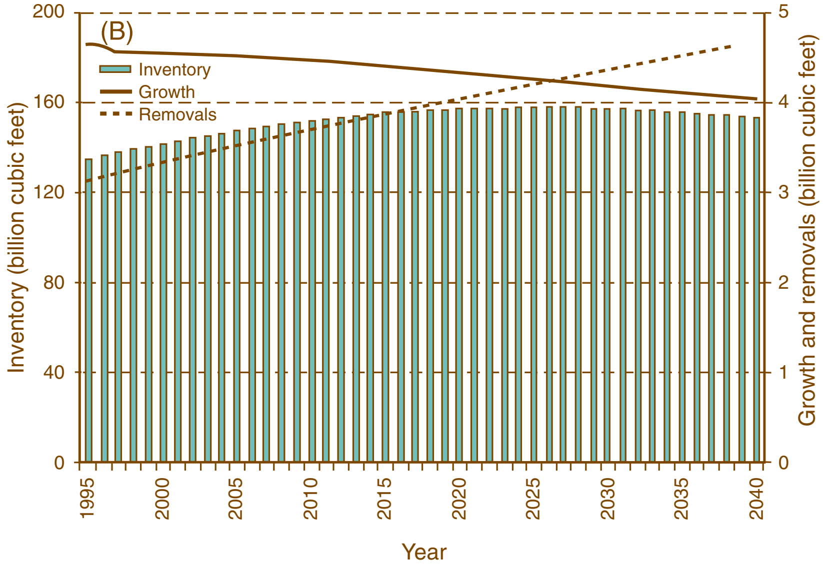
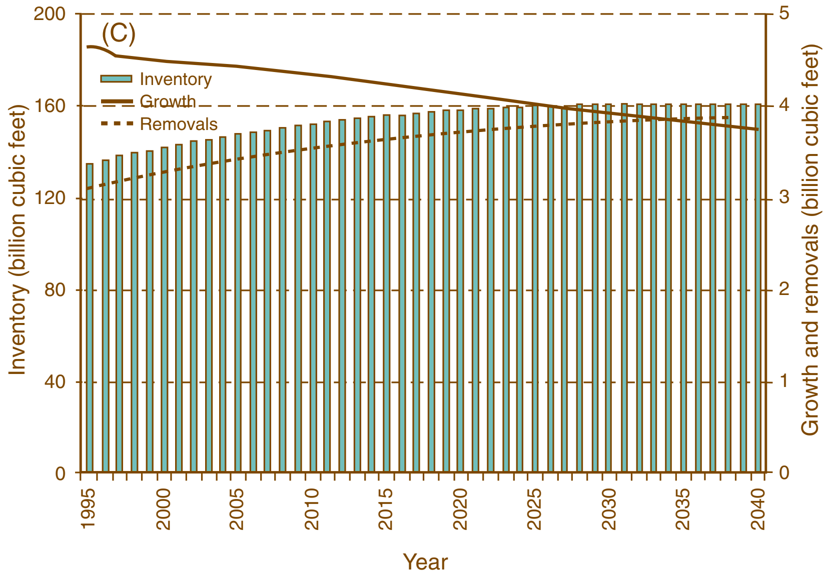
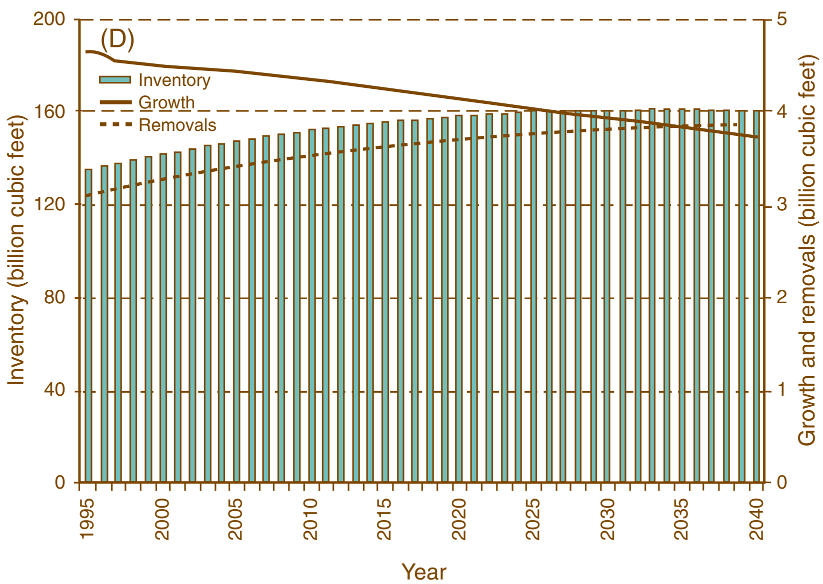


Figure 13.23—Subregional Timber Supply Model projections of hardwood timber growth and removals volumes on private timberland in the South, 1995 to 2040, under four assumptions: (A) IH or base case—inelastic timber demand and high plantation volume growth rates, (B) IL—inelastic timber demand and low plantation volume growth rates, (C) EH—elastic timber demand and high plantation volume growth rates, and (D) EL—elastic timber demand and low plantation volume growth rates.







plantations, which yield wood at least 50 percent faster than natural pine. Rising productivity over time means that more wood can be produced on a smaller land base.

For hardwoods, the lack of a technology that substantially increases growth means that growth is projected to stay ahead of removals for only two to three decades, after which hardwood inventory is projected to decline. This finding is common to all scenarios and is displayed graphically in figure 13.23. In the base case scenario, growth is projected to exceed removals until about 2025, when removals overtake growth. Much of the high rate of removals increases can be ascribed to a growing demand for hardwood fiber for engineered wood products, especially structural and nonstructural wood panels (Haynes and others 2002).

Hardwood harvests from private lands are projected to change unevenly across the South. In percentage terms, projected increases are largest for northern and western parts of the South (Kentucky, Tennessee, northern Alabama, northern Arkansas) and for southern Florida. In the northern portions, these harvests are mostly from areas not projected to lose forests. In Florida, however, many of these harvests are projected to be associated with conversion from forest to urban uses (fig. 13.24A). In volume terms, the story is more complex, reflecting a combination of hardwood volumes entering the market during conversion from forest to nonforest uses, volumes entering the market during conversion of hardwood types to pine plantations, and higher harvesting rates in hardwood forests that are projected to remain hardwood forests (fig. 13.24B).

Across all States and species combined, projected trends for growth and removals differ by ownership in the IH (fig. 13.25A), IL (fig. 13.25B), EH (fig. 13.25C), and EL (fig. 13.25D) scenarios. In both the IH and the IL scenarios, until about 2030, growth is projected to exceed removals on NIPF timberland. On industry-owned land, growth is projected to exceed removals throughout the projection period. Under both elastic (EH, EL) scenarios, growth is projected to exceed removals for both NIPF and industry ownership groups in aggregate throughout the

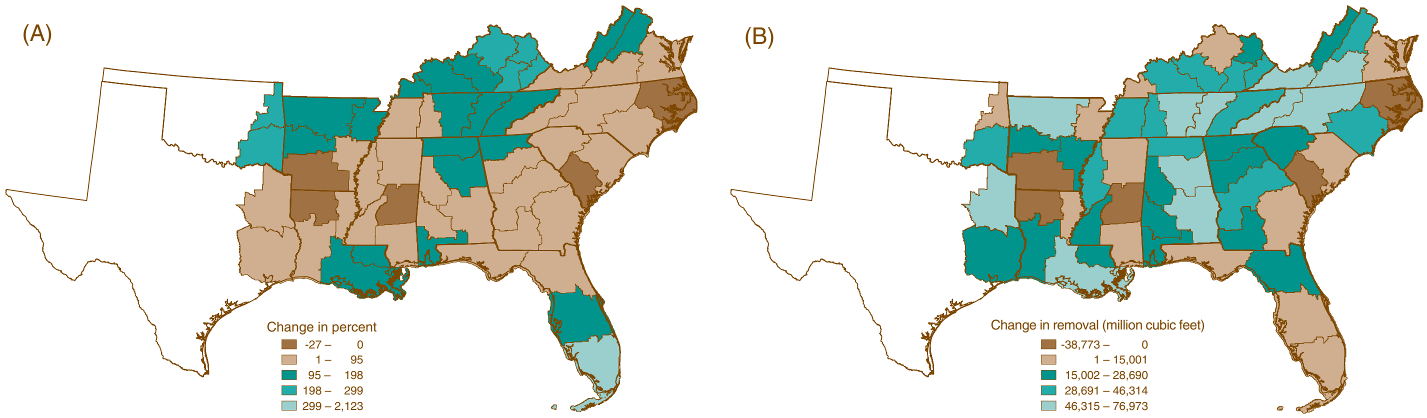


Figure 13.24—Percentage (A) and absolute (B) changes in annual hardwood harvest levels on private timberland in the South, 1995 to 2040, as projected by the Subregional Timber Supply Model, by USDA Forest Service, Southern Research Station, Forest Inventory and Analysis survey unit, under IH (base case) assumptions of inelastic demand and high plantation volume growth rates.

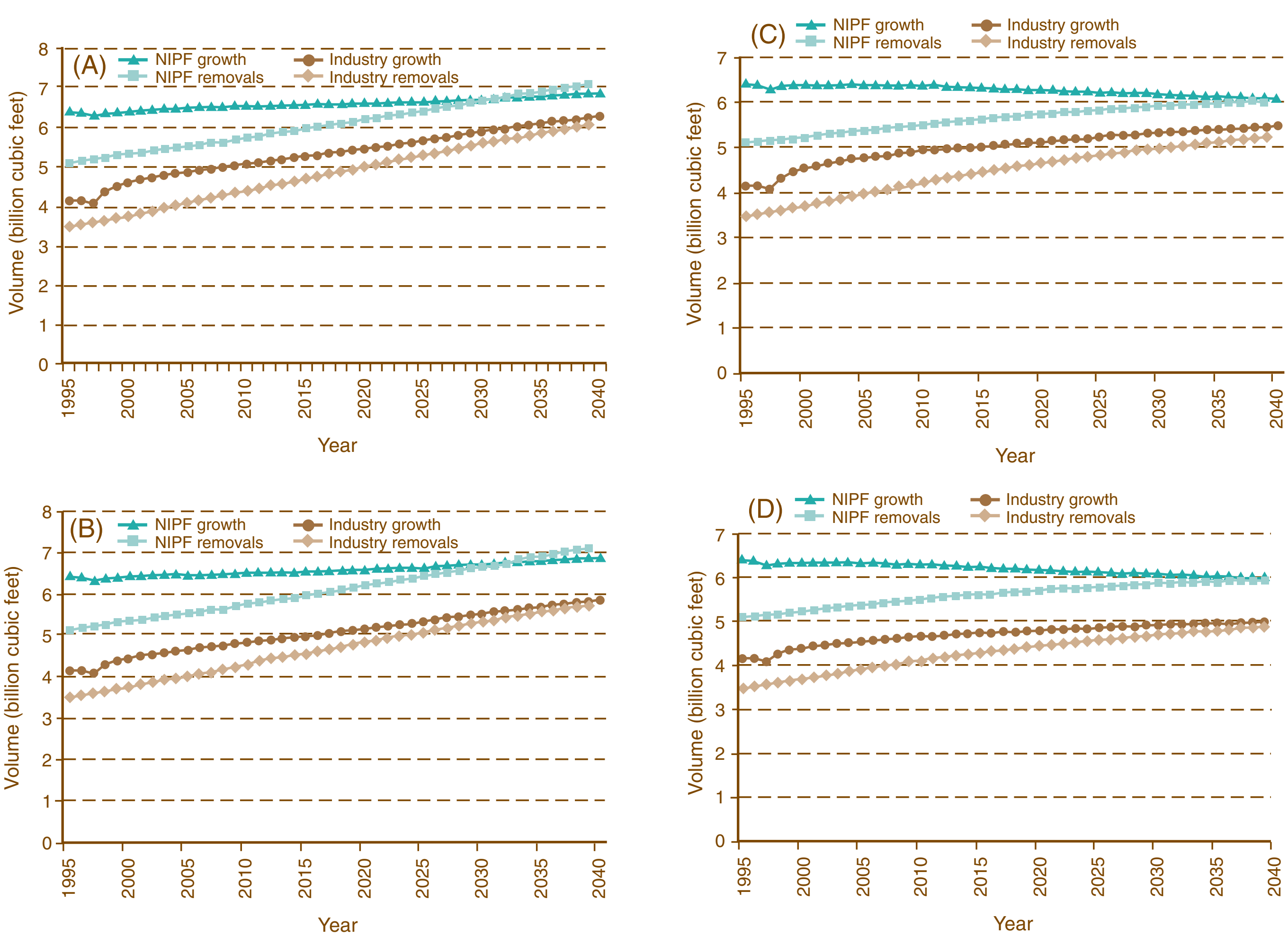


Figure 13.25—Subregional Timber Supply Model projections of total timber growth and removals volumes on private timberland, by ownership group, 1995 to 2040, under four assumptions: (A) IH or base case—inelastic timber demand and high plantation volume growth rates, (B) IL—inelastic timber demand and low plantation volume growth rates, (C) EH—elastic timber demand and high plantation volume growth rates, and (D) EL—elastic timber demand and low plantation volume growth rates [nonindustrial private forest (NIPF)].

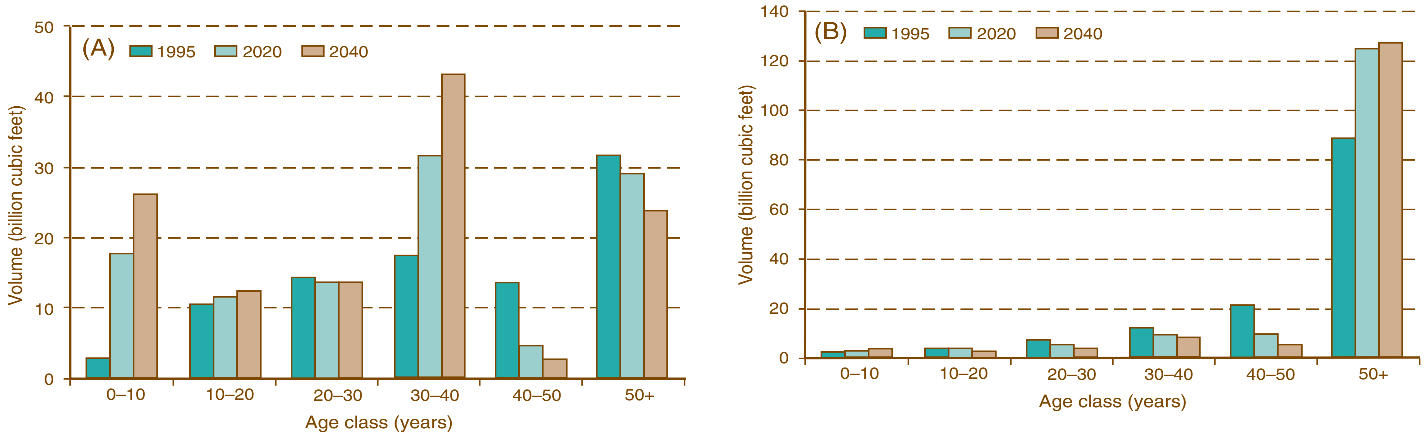


Figure 13.26—Subregional Timber Supply Model projections of softwood (A) and hardwood (B) age structure (volume by age class) on private timberland, Southwide, 1995, 2020, and 2040, under the IH (base case) scenario of inelastic timber demand and high plantation growth rate increase.

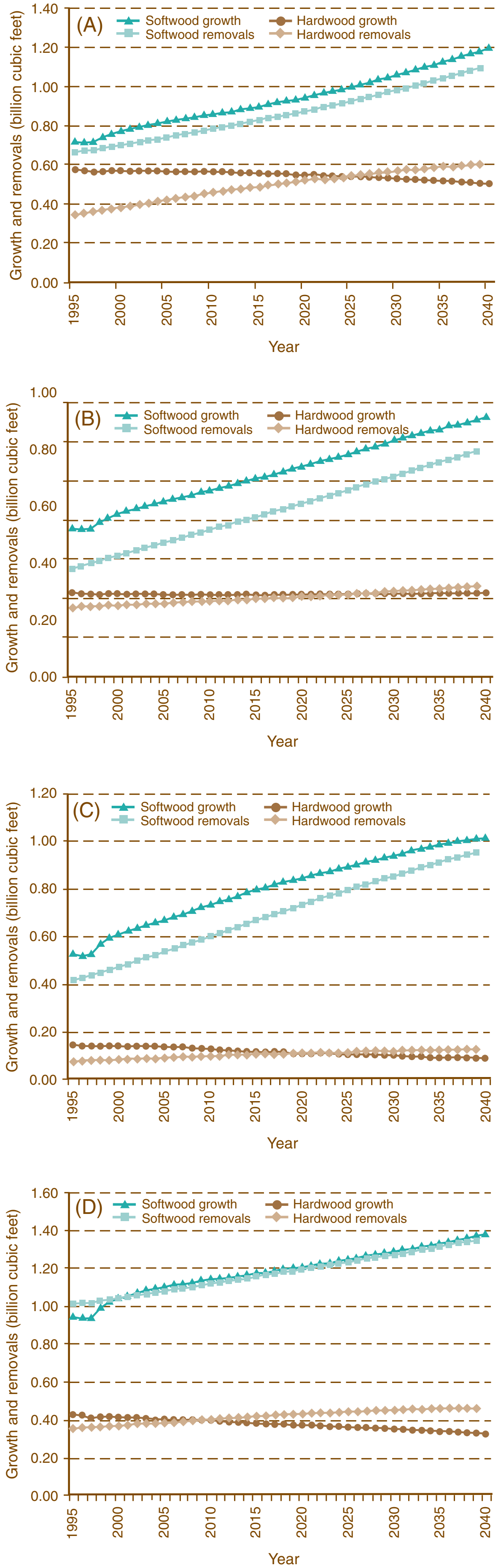
projection. The different trends on NIPF and industry land in the inelastic scenarios occur because forest industry landowners are projected to invest heavily enough in plantations that their higher growth would keep up with the relatively inelastic and increasing demand. NIPF owners, however, have more land in natural forest management types, which are projected to decline in area over time, and their pine plantations are not projected to improve in productivity as much as industry plantations.

Changes in management type acreages toward more acres in pine plantations and fewer acres in natural forest management types on private lands will affect age structure of southern forests. Softwood forests are projected to become younger (fig. 13.26A shows this for the base case). Part of the increase in the younger age classes is caused by pine plantations being harvested by around age 30 years, while the natural pine (natural pine and the pine in mixed oak-pine) will be harvested at a higher age. The amount of such natural pine in private ownership is projected to decline. Hardwood forests are projected to become somewhat bifurcated in age structure, with a growing share of volume residing in older age classes and a shrinking share in the middle age classes (10 to 40 years) (fig. 13.26B). The shrinking middle age classes in hardwood result mostly from relatively lower harvesting pressure (relative to pine) in this type. Much of the middle-aged volume therefore enters the oldest age classes over time.

Southwide changes in inventory resulting from private timberland area changes, management type area changes, and plantation growth mask variations on those changes on smaller spatial units. For most States, inventories of both hardwood and softwood are projected to always exceed those present in 1995. This finding can be obtained by examining the differences between growth and removals for both hardwood and softwood: when growth exceeds removals, inventory increases; when removals exceed growth, inventory declines. Figure 13.27A shows the growth and removals projections for Alabama, while analogous figures are offered for Arkansas (fig. 13.27B), Florida (fig. 13.27C), Georgia (fig. 13.27D), Kentucky (fig. 13.27E), Louisiana (fig. 13.27F), Mississippi (fig. 13.27G), North Carolina (fig. 13.27H), Oklahoma (fig. 13.27I), South Carolina (fig. 13.27J), Tennessee (fig. 13.27K), Texas (fig. 13.27L), and Virginia (fig. 13.27M). Across most States, growth and removals of both hardwood and softwood species are projected to increase through 2040. Some exceptions are in Mississippi and South Carolina, where hardwood removals outpace growth during the entire projection. The falling hardwood inventories can be ascribed primarily to vigorous conversion of natural forest management types to pine plantations. Softwood inventories in both States are projected to rise through 2040. Kentucky and Oklahoma, with large inventories relative to local demand, are projected to have steadily rising inventories of both hardwood and softwood throughout the projection.

Timber prices are useful indicators of timber scarcity or abundance. Prices are projected to go up in real (adjusted for inflation) terms between 1995 and 2040 under all scenarios and for both softwood (fig. 13.28A) and hardwood species (fig. 13.28B). The prices reported here are the aggregate of all size classes of timber (pulpwood, sawtimber). Under both of the inelastic (IH, IL) timber-demand scenarios, softwood timber prices are projected to increase by at least two-thirds between 1995 and 2040. Under the elastic scenarios (EH, EL), these prices are projected to increase by 8 to 10 percent. For hardwood, a similar story emerges: under IH and IL, prices are projected to rise by about 82 percent, while under the EH and EL scenarios, the increase is 10 percent. Thus, real price increases will serve as incentives for continued investment in intensive timber growing technologies. Rising prices therefore help to counteract the trend toward land conversion away from forest, while such price trends also encourage forest type conversions to plantations and, to a lesser extent, agricultural land reversions to forest.

The effects of rising timber prices may be felt in the timber product sector by inducing substitutions and technology changes. The SRTS model used in this



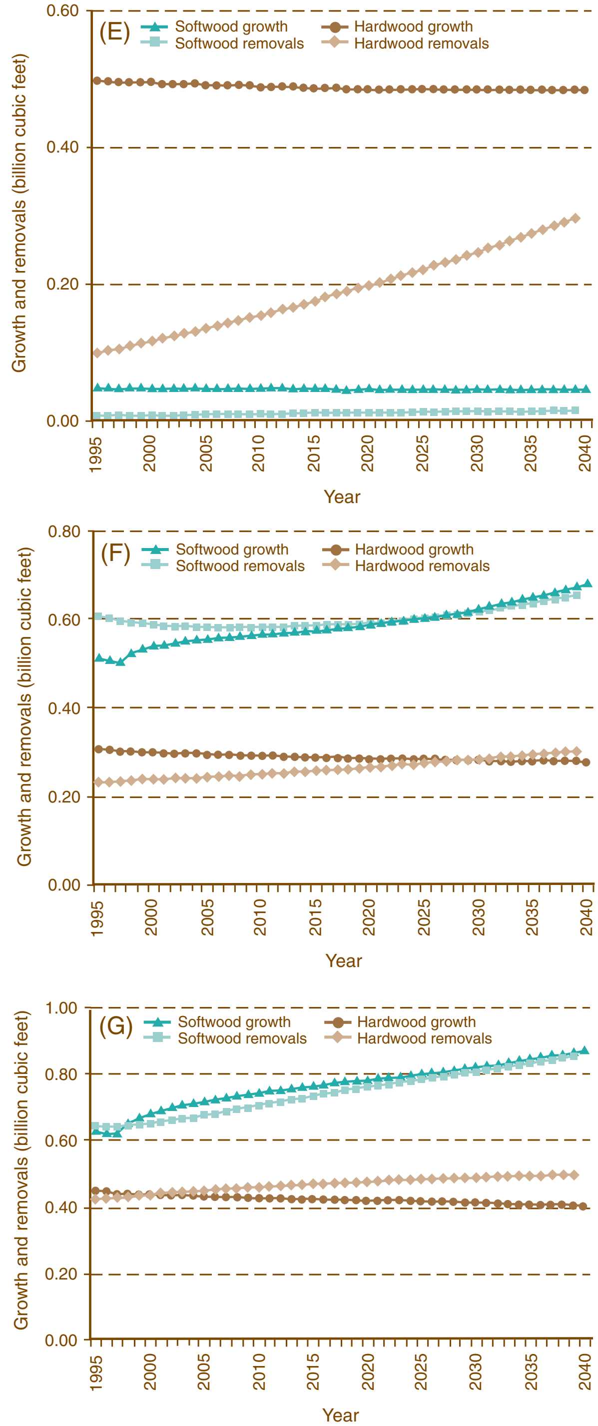
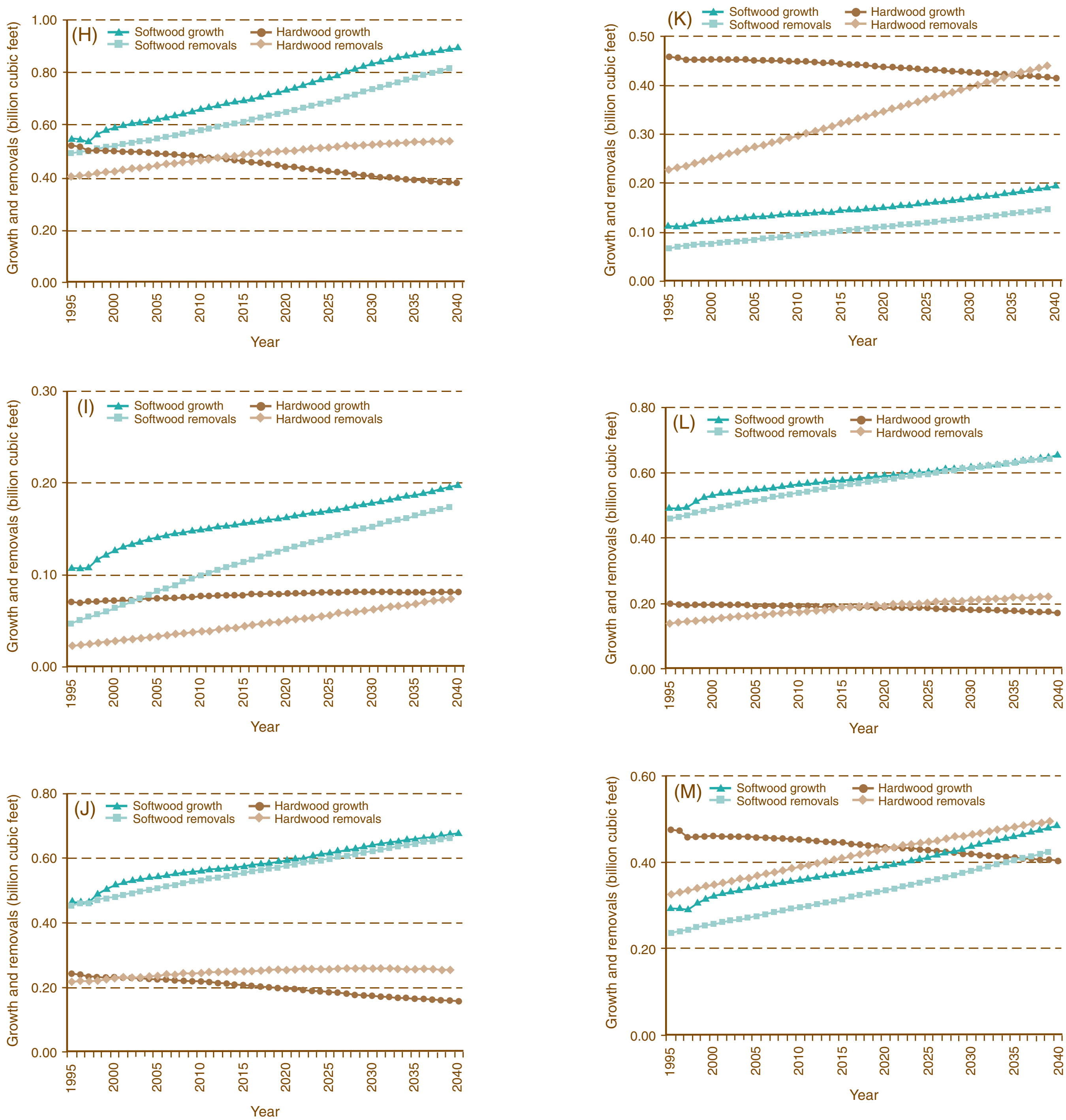


Figure 13.27—Subregional Timber Supply Model projections of Alabama (A), Arkansas (B), Florida (C), Georgia (D), Kentucky (E), Louisiana (F), Mississippi (G), North Carolina (H), Oklahoma (I), South Carolina (J), Tennessee (K), Texas (L), and Virginia (M) softwood and hardwood growth and removals volumes on private timberland, 1995 to 2040, under the IH (base case) scenario of inelastic timber demand and high plantation growth rate increase.



Assessment does not have a mechanism for directly incorporating such dynamics. It is clear, however, that higher timber prices translate to higher incomes for timber producers. Timber price increases, on the other hand, mean that final product prices also will rise (though not necessarily in proportion) in a manner similar to that projected under the timber demand-and-supply scenarios outlined here. Consumers of these products will be encouraged, through price rises, to substitute nonwood products for wood products in the construction industry. Paper product manufacturers may also have a rising incentive to seek greater imports of pulp fiber, use more recycled fiber furnish, and further increase the efficiency of fiber use. It is also possible that the mix of timber products will shift over time, as timber is harvested at a younger age. Because smaller trees are generally less suitable for solid wood products, rising wood prices will continue the trend toward greater use of engineered wood products.

Discussion and Conclusions

The Southern United States is the largest single producer of timber products in the World. Most of the region's production comes from private land and is consumed domestically, and projections suggest that these facts will remain unchanged. The South has become increasingly prominent in domestic timber product markets

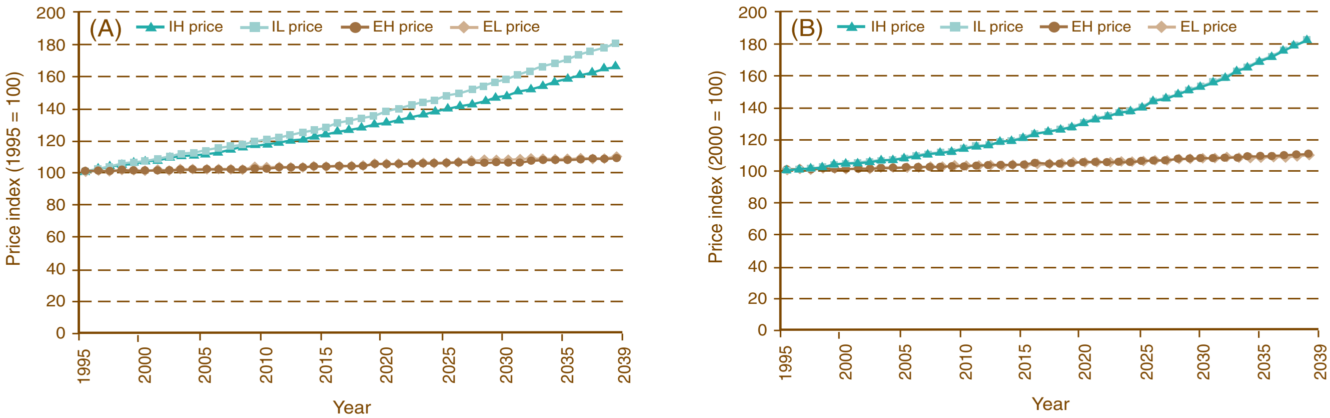


Figure 13.28—Subregional Timber Supply Model projections of softwood (A) and hardwood (B) timber prices, 1995 to 2039, under all scenarios.

TIMBER

because of rapidly increasing productivity on private land, improved product manufacturing technology, and the shrinking timber harvests in other parts of the country. Projections of the Draft 2000 RPA show that the South will remain the Nation's dominant timber producing region, and those of SRTS given here appear to support that finding. Continued dominance over the next several decades will be enabled by steadily advancing technology in timber growing and wood utilization and by limited harvest increases in other parts of the United States. The South's dominant role will depend partly on an increasing rate of harvest of hardwood resources. Hardwood volume growth will outpace harvest volume for at least 25 to 30 years. Southern industrial and nonindustrial timberland owners are expected to continue to invest in and expand the area of pine plantations. Faster growth, permitted by genetic improvements, more intensive use of mechanical and chemical means of competition control and greater use of fertilizers, and higher harvest frequency of such plantations enable substantial increases in aggregate output of softwood. Despite the rising role of the South and the rapid rise in production from pine plantations, output is not projected to keep pace with demand expansion, and higher prices are projected to be the result. The rising prices will likely mean rising product imports and continued changes in product manufacturing technologies, which will combine to partially offset the effects of more expensive timber on the prices of wood-based final products.

One result of the projected increasing prevalence of pine plantations is a continued decrease in the area of private timberland in natural forest management types. Part of the loss of natural types, however, comes from the liquidation of forests to accommodate urban expansion. Such land use pressures are projected to depress the total area of timberland in some parts of the South, especially in the heavily populated Atlantic Coast States from Virginia to Florida. The loss of timberland there is projected under the base case scenario to be offset in the aggregate by the gains in some parts of the northern and western regions of the South.

The projected increase in acreage and growth rate of southern pine plantations implies that forest product manufacturing opportunities will improve. Investment opportunities will exist for developing capacity and technology to utilize small diameter logs coming from pine plantations. But such rising economic opportunities may have to be squared with, or be limited by, issues surrounding the losses of some ecological values associated with the losses of natural management types. We note that the private forests of South are not projected to be dominated by pine plantations. Although the projected rise in pine plantation area is to match the projected fall in timberland in natural forest management types in our base case scenario, natural types in all scenarios are projected to be the dominant kind of private timberland in the region in 2040. In some places, such as southern Georgia and northern Florida, however, pine plantations are projected to dominate the landscape. Along the Atlantic and Gulf Coastal Plains from North Carolina to Texas, pine plantations are projected to be the largest single forest management type, but they will not comprise a majority of forests on most of the Coastal Plain. Nevertheless, a question remains as to whether the large plantation acreage increases projected for some regions under some scenarios would be acceptable to local residents, for whatever reasons, or whether any local opposition to them would stop them from being established.

The projections reported here are based on validated empirical models of land use, timber supply-and-demand relationships, and reasonable assumptions about timber demand growth. The projections rely on what have been shown to be relatively stable patterns of product consumption, economic growth, technological change, population growth, and land use choices. As with all such models, projections are contingent on the stability of economic relationships, consumer tastes, and assumptions about changes in national and World economies. Further, the emergence and success of not yet conceived technologies is impossible to gauge. We caution, therefore, that because these relationships, consumer preferences, technologies, and other factors will change in the future, the reliability of such a projection becomes progressively lower as the time projected into the future increases.

The forest sector depends heavily on long production periods and large capital investments, and these characteristics would seem to work in favor of making valid projections of the future. People can be reasonably expected to continue to demand wood for furniture and housing and paper for packaging and writing. Hence, projections about the sector over coming decades can be made with some confidence by evaluating the growth of trees already in the ground and timber product manufacturing capacity already in place. As a result, forest sector projections may be more reliable than similar projections made for other sectors of the economy. Nevertheless, the details of projections are notoriously unreliable. Hence, one should not view the projected dates of key thresholds, peaks, and troughs with confidence. Instead, one should view the projections as maps of overall trends if current consumer preferences, supply-and-demand relationships, and trends in technology remain stable. Expect the future of projected variables to mimic the bumpiness of the past, when there were periods of increases and periods of decreases in timberland area, harvests, prices, product shares, and trade.

Needs for Additional Research

Most of the issues identified by the public and by forest sector analysts were addressed in some way in this chapter. Some issues could not be addressed due to data limitations and a lack of a complete understanding of certain structural relationships. First, many of the linkages between competing products, e.g., hardwood as a substitute for softwood timber, the substitution of nonwood products for products made from wood fiber, could not be evaluated because of a lack of solid empirical estimates of those linkages. Expanded understanding of those relationships through empirical modeling would improve the accuracy of SRTS as well as RPA projections of the kinds reported here. Further, in SRTS modeling, projections could not be made with confidence at scales smaller than the survey unit of where pine plantations would be established and hence which natural forest management types would be lost there as a result. Improved understanding of how decisions are made for locating plantations would improve the level of detail offered by SRTS.

The South is undergoing rapid urbanization, and the land use projections arising from SRTS modeling suggest that this trend will continue. Demographics of landowners will change as the population ages and becomes wealthier. Urbanization and demographic changes are likely to result in increased fragmentation of both forests and their ownership, but we do not know how much new fragmentation will occur or how it may affect the values and commodities obtained from forests. Better estimates of land use and forest type trends at fine spatial scales could result from a better understanding of fragmentation and urbanization.

Highlighted in this chapter are large historical and projected future increases in pine plantation timberland area and decreases in the timberland area of natural forest management types in private ownership. The pine plantation area projections can be made at the FIA level, but this level of model resolution is not adequate for projecting the effects of economic and demographic trends on pine plantations at the kinds of finer spatial resolution that would be useful for making many kinds of ecological and economic projections. A new generation of land use models that can predict with accuracy the proportion of forest in pine plantations on small spatial units, such as at the scale of counties or finer, would therefore make such projections more useful. To develop such empirical models, however, reliable data are needed on land uses and the relevant driving variables in those finer spatial units.

A key issue for further research is better understanding of how sustainability policies affect timber supply, demand, and the ecological characteristics of forests. Sustainability of forest uses in the South might be assured through more stringent government regulation of private landowners. Alternatively, sustainability could result from changes in consumer preferences and induced through commodity markets. In either case, the expense of managing and harvesting timber would change, affecting timber supply-and-demand. More complete understanding of the effects of sustainability policies could facilitate decisionmaking in both private and public sector planning and policy development.

An emerging issue that may merit investigation for its potential impacts on timber supply-and-demand is the promulgation of laws or the appearance of market incentives to sequester carbon in forests. Sequestration, done to reduce atmospheric carbon and mitigate apparent climate change, could be encouraged through subsidies, tax incentives, regulations, or voluntary creation of a national or World carbon-credit trading system. In any case, sequestration would probably involve longer rotation lengths (forest growing periods) and larger diameter trees, and so there would be ecological and timber product market consequences. Timber product markets reliant on large-diameter materials, e.g., sawtimber, might grow relative to markets utilizing primarily small diameter materials, e.g., pulpwood; but quantifying the full effects of alternative policies and market mechanisms would be useful to policymakers, climate modelers, and the timber product sector.

Finally, little is known about the potential effects on timber markets of introducing short-rotation woody crops into the fiber supply. These crops, often of hardwood tree species, would produce a kind of fiber useful for certain products (especially printing and writing papers and nonstructural panels) and not others. New sources of fiber could dampen the hardwood pulpwood price increases that have been projected for the future in this Assessment and could affect land use and timber production patterns. Little is known about where these woody crops would be grown, the scale of their production, or their ecological implications. But the prospect of their emergence merits new investigation.

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Literature Cited

Abt, R.C.; Cubbage, F.W.; Pacheco, G. 2000. Southern forest resource assessment using the subregional timber supply (SRTS) model. Forest Products Journal. 50(4): 25–33.

Adams, D.; Haynes, R. 1996. The 1993 timber assessment market model: structure, projections, and policy simulations. Gen. Tech. Rep. PNW–GTR–368. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p.

Bailey, R.G. 1995. Description of the ecoregions of the United States. Misc. Publ. 1391. Washington, DC: U.S. Department of Agriculture. 108 p.

Barbier, E.B. 1996. Impact of the Uruguay round on international trade in forest products. Rome, Italy: Food and Agriculture Organization of the United Nations. [Number of pages unknown].

Bonnefoi, B.; Buongiorno, J. 1990. Comparative advantage of countries in forest-products trade. Forest Ecology and Management. 36: 1–17.

Castillo, S.; Laarman, J.G. 1984. A market-share model to assess price competitiveness of softwood lumber exports to Caribbean markets. Forest Science. 30: 928–932.

Dodrill, J.D.; Cubbage, F.W. 2000. Potential wood chip mill harvest area impacts in North Carolina. Report prepared for the study on: economic and ecologic impacts associated with wood chip production in North Carolina. Raleigh, NC: Southern Center for Sustainable Forests, North Carolina State University, Duke University, and the North Carolina Division of Forest Resources. 25 p. On file with: Southern Research Station, Forestry Sciences Laboratory, P.O. Box 12254, Research Triangle Park, NC 27709.

Guan, H.; Munn, I.A. 2000. Harvest restrictions: an analysis of new capital expenditures in the Pacific Northwest and the South. Journal of Forestry. 98(4): 11–17.

Hair, D. 1963. The economic importance of timber in the United States. Misc. Publ. 941. Washington, DC: U.S. Department of Agriculture. 91 p.

Hardie, I.; Parks, P.; Gottleib, P.; Wear, D.N. 2000. Responsiveness of rural and urban land uses to land rent determinants in the U.S. South. Land Economics. 76(4): 659–673.

Haynes, R.; Adams, D.; Alig, R. [and others]. 2002. The 2000 RPA timber assessment: an analysis of the timber situation in the United States, 1952 to 2050. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. [RPA timber assessment homepage]. http://www.fs.fed.us/pnw/sev/rpa/. [Date accessed: May 3, 2002].

Hyldahl, C.A.; Hansen, B.G.; West, C.D. 2000. Hardwood chips: production, consumption, and exports. In: Society of American Foresters National Convention. Washington, DC: [Society of American Foresters]. [Poster]. [Number of page unknown].

Ince, P. 2000. Industrial wood productivity in the United States, 1900–1998. Res. Note FPL–RN–0272. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 14 p.

Johnson, T.G. 1996. Trends in southern pulpwood production, 1953–1993. Resour. Bull. SRS–3. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 24 p.

Johnson, T.G.; Howell, M. 1996. Southern pulpwood production, 1994. Resour. Bull. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 40 p.

Johnson, T.G.; Steppleton, C.D. 1996. Southern pulpwood production, 1995. Resour. Bull. SRS–8. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 40 p.

Johnson, T.G.; Steppleton, C.D. 1997. Southern pulpwood production, 1996. Resour. Bull. SRS–21. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 40 p.

Johnson, T.G.; Steppleton, C.D. 1999. Southern pulpwood production, 1997. Resour. Bull. SRS–37. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 40 p.

Johnson, T.G.; Steppleton, C.D. 2000. Southern pulpwood production, 1998. Resour. Bull. SRS–50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 40 p.

Louisiana Department of Agriculture and Forestry. 2000. Quarterly report of forest products data: 1955 to current report. Baton Rouge, LA: Office of Marketing. [Date accessed: August 13, 2002]. http://www.ldaf.state.la.us/divisions/forestry/reports/quarterreport/original-report.asp.

Murray, B.C.; Lee, K.J. 1990. An econometric model of private land management in Georgia. In: Hickman, C.A., ed. Proceedings of the southern forest economics workshop on evaluating even- and all-aged timber management options for southern forest lands. Gen. Tech. Rep. SO-79. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 81–87.

Murray, B.C.; Wear, D.N. 1998. Federal timber restrictions and interregional arbitrage in U.S. lumber. Land Economics. 74(1): 76–91.

Phelps, R.B. 1980. Timber in the United States economy, 1963, 1967, and 1972. Gen. Tech. Rep. WO–21. Washington, DC: U.S. Department of Agriculture, Forest Service. 90 p.

Powell, D.S.; Faulkner, J.L.; Darr, D.R. [and others]. 1994. Forest resources of the United States, 1992. Gen. Tech. Rep. RM–234. Revised. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 133 p.

Prestemon, J.P.; Buongiorno, J. 1996. The impacts of NAFTA on U.S. and Canadian forest product exports to Mexico. Canadian Journal of Forest Research. 26(5): 794–809.

Prestemon, J.P.; Butry, D.T.; Pye, J.M.; Stratton, D.T. 2001a. Locations of southern wood chip mills for 2000. [Database]. http://www.rtp.srs.fs.fed.us/econ/data/mills/mills.htm. [Date accessed: July 3, 2002].

Prestemon, J.P.; Pye, J.M. 1999. Mill locations. [Database]. http://www.rtp.srs.fs.fed.us/econ/data/mills/mills.htm. [Date accessed: July 3, 2002].

Prestemon, J.P.; Pye, J.M.; Butry, D.T.; Stratton, D.T. 2001b. Locations of southern wood chip mills for 2000. [Database]. http://www.rtp.srs.fs.fed.us/econ/data/mills/mills.htm. [Date accessed: July 3, 2002].

Trømborg, E.; Buongiorno, J.; Solberg, B. 2000. The global timber market: implications of changes in economic growth, timber supply, and technological trends. Forest Policy and Economics. 1(1): 53–69.

United Nations Food and Agricultural Organization. 2000a. Direction of trade, 1997. [Database]. http://apps.fao.org/page/collections?subset=forestry. [Date accessed: July 3, 2002].

United Nations Food and Agricultural Organization. 2000b. FAOSTAT forestry data. http://apps.fao.org/page/collections?subset=forestry. [Date accessed: July 3, 2002].

U.S. Department of Agriculture, Forest Service. 1958. Timber resources for America's future. For. Resour. Rep. 14. Washington, DC: U.S. Department of Agriculture, Forest Service. 713 p.

U.S. Department of Agriculture, Forest Service. 1982. An analysis of the timber situation in the United States 1952–2030. For. Resour. Rep. 23. Washington, DC: U.S. Department of Agriculture, Forest Service. 499 p.

U.S. Department of Agriculture, Forest Service. 2000. Timber harvested on the national forests under sales and land exchanges by regions and fiscal years. Washington, DC: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Waddell, K.L.; Oswald, D.D.; Powell, D.S. 1989. Forest statistics of the United States, 1987. Bull. PNW–RB–168. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 106 p.

Chapter 14: Intensive Timber Management Practices

What are the status and trends of forest management practices in the South?

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Key Findings

- Forest management in the South has intensified over the past two decades, and this trend is expected to continue.
- Intensive planted pine technology nearly doubles growth-and-yield rates and offers superior investment returns compared to more traditional management composed only of site preparation and planting.
- Planted pine management intensity is expected to continue to grow as forest industry and timberland management organizations increase investment on their land.
- Hardwood forests are managed less intensively in natural stands.
- Intensive management is difficult and more expensive on smaller tracts; increasing fragmentation of forests in the South will exert downward pressure on management intensity.
- Forestry incentives programs have supported tree planting, management planning, and improvement of forest management practices, substantially increasing planted pine area, timber production returns, and environmental benefits.

Introduction

Timber harvests in the South have taken advantage of a substantial accumulation of forest-growing stock and considerable investment in timber growing over the past four decades. As some forest owners adopt more intensive forest management, the production potential of forests changes accordingly. Planting genetically improved stock and applying fertilizer and herbicide will increase growth, yield and long-run timber supply. This chapter assesses the status of forest management in the South. It describes both the types and extent of silvicultural treatments in the region. It also analyzes costs and returns from intensive management practices.

Methods

Applied approaches included statistical data analysis, growth-and-yield analysis, capital budgeting analysis, and literature review. The first step in assessing the status and trends of forest management practices in the South involved analysis of forest inventory statistics. Effects of particular plantation management practices on productivity were estimated from a forest industry survey, which served as a baseline for the development of planted pine growth-and-yield tables. The survey's results were used to develop five planted pine management-intensity classes. Management treatments included site preparation, planting of genetically improved seedlings, applications of fertilizer and herbicide, and thinning.

The TAUYIELD model was used to evaluate effects of these management treatments on growth and yield. TAUYIELD is a stand-level growth-and-yield model for unthinned and thinned loblolly pine plantations (Amateis and others 1995). The model estimates number of trees, average height, basal area, and volume by diameter at breast height (d.b.h.) class.

Growth-and-yield analysis was the first step in the evaluation of the impact of forest investment on forest conditions and productivity. Capital budgeting analysis, which discounts the cash flow of investments, was used to develop financial indicators such as net present values (NPVs), soil expectation values (SEVs), and internal rates of return (IRRs). These measures were used to determine whether intensive forest management generates attractive returns. This step was supplemented with results of surveys of forest owners. Forest industry (FI), timberland management organizations (TIMOS), and nonindustrial private forest (NIPF) owners were asked about their current and future management approaches. Results permitted inferences about likely future management intensities and their impact on forest conditions and productivity.

Data Sources

Reports from USDA Forest Service Forest Inventory and Analysis (FIA) units, State forestry organizations, literature, industry associations, and research cooperatives were the primary data sources for the analysis.

Two most recent rounds of FIA surveys (with the exception of Kentucky, where only 1988 FIA survey data were available) were used to determine the status and trends of specific forest management practices that can be observed and recorded on sample plots. For all States, except Kentucky, the latest FIA survey measurement year is in the 1990s. The earlier of the FIA surveys were conducted between 1982 and 1989.

Average measurement years for the latest and earlier rounds of the FIA surveys are 1993 and 1986, respectively.

Management practices represented by FIA data include clearcutting, partial cutting, thinning, timber stand improvement (TSI), site preparation, burning, planting, and natural regeneration. Because there were some differences between the Southeast region (Florida, Georgia, North Carolina, South Carolina, Virginia) and the South-Central region (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas) and between particular States in defining management practices and data collection standards, some adjustments had to be made to develop Southwide forest management practices categories.

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In the Southeast, partial cutting, seed-tree cutting, and salvage cutting categories were merged into one partial cutting category that corresponds to the South Central's partial cutting category. Similarly, in the South Central, thinning, commercial thinning, and precommercial thinning categories were merged into one thinning category that corresponds to the Southeast's thinning category.

In the Southeast prescribed burning was classified, depending on purpose, as site preparation or other prescribed burning, whereas in the South Central burning could be included in both site preparation and burning categories. This situation raises some concerns with double counting in site preparation and burning categories and the confusion of prescribed burning with wildfires. In Kentucky, burning disturbance was recorded without notation of purpose, and no thinning, timber stand improvement, or site preparation information was noted.

Finally, adjustments had to be made in developing Southwide planting and natural regeneration estimates. In the Southeast, FIA recorded information about planting, afforestation, and natural regeneration. The same information was not available for the South Central. Planting and natural regeneration rates there were developed using stand origin and age variables. This approach yielded only approximate results because FIA used regression results to assign stand ages to sample plots that originally were in a mixed-age category. These problems and assumptions indicate that the results based on FIA data are only moderately accurate.

Since FIA data provide no information about the use of genetically improved stock, fertilizer and herbicide application, or uneven-aged silviculture, other information sources had to be used. These data sources include industry associations, research cooperatives reports, and forest owner surveys.

In particular, the North Carolina State Forest Nutrition Cooperative (2000) provided information about fertilizer application. Forest owner surveys by the Southern Forest Resources Assessment Consortium (SOFAC) and the American Forest and Paper Association (AF&PA) provided information about management intensities on FI, TIMOS, and NIPF timberlands (Moffat and others 1998, Siry 1998, Siry and Cubbage 2001, Siry and others 2001). The surveys and literature review provided information on multiple-use intentions and outcomes, “no active management” approaches, and forestry incentives programs.

Where possible, information was provided by ownership group. FIA data provided information for public (PB), forest industry (FI, includes company and leased land), miscellaneous corporate (MC), and NIPF owner groups. SOFAC and AF&PA surveys provided information for FI, TIMOS, and NIPF owners.

Results

Forest management in the South has intensified over the past two decades. Practices associated with intensive forest management are used more frequently and on larger areas than ever before. These practices include clearcutting, partial cutting, TSI,

Table 14.1—Current status and trends in annual use of forest management practices by forest type based on FIA data

Treatment	Forest management type							
	Planted pine	Natural pine	Oak-pine	Upland hardwood	Bottomland hardwood	Not stocked	Total	Change between FIA surveys
	Thousand acres per year							*Percent*
Clearcut	435.1	188.4	347.4	778.4	266.9	6.4	2,022.7	9.5
Partial cut	344.4	577.2	663.2	1,322.3	395.8	6.2	3,309.2	12.4
Thinning	308.2	179.8	97.6	46.7	10.5	0	642.8	2.5
TSI	285.1	362.7	163.2	116.5	12.4	1.5	941.5	74.4
Site prep.	709.0	66.4	195.7	179.5	28.8	3.4	1,182.7	1.0
Burning	667.7	761.2	409.2	392.1	53.5	4.8	2,288.5	-3.5
Planting	1,237.1	NA	226.0	165.7	12.4	2.0	1,643.3	25.2
Natural regen.	NA	300.2	319.1	815.7	242.9	23.5	1,701.5	18.0

TSI = timber stand improvement.

planting and natural regeneration, and chemical applications. Thinning and site preparation experienced smaller increases, while burning became less common. Intensified planted pine management nearly doubles yields compared to traditional management approaches. While it is more expensive than traditional management, capital budgeting analysis indicates that intensive management generates superior returns. Compared with planted pine, hardwood forests are managed less intensively in natural stands. Their management intensity is expected to increase moderately. Attractive planted pine returns and stated future forest management intentions indicate that forest management intensity in the South will continue to grow.

Trends in Use of Specific Forest Management Practices

Tables 14.1 and 14.2 show FIA results regarding current annual use and trends in use of forest management practices, including clearcutting, partial cutting, thinning, TSI, site preparation, burning, planting, and natural regeneration.

Clearcutting occurs on about 2 million acres annually. Upland hardwood accounts for 38 percent of harvested land and is followed by planted pine with 22 percent. The area of clearcut planted pine is probably higher as planted pine stands with a larger hardwood component are classified as oak-pine. If this indeed is the case, then planted pine clearcut area would be similar to upland hardwood. Clearcutting is most common on NIPF land, which accounts for 57 percent of harvested area. This result is an expected result because NIPF owners hold the majority of timberland in the region. Acreage of clearcutting has grown by nearly 10 percent over the period covered by the FIA surveys, or a 1.4-percent annual increase from 1986 to 1993. While clearcutting increased on PB, NIPF, and MC land, it actually decreased on FI land. The total annual clearcut area amounts to only about 1 percent of timberland area in the region. This result indicates that management is relatively extensive in the South's timberland. Partial cutting is much more widespread, occurring on about 3.3 million acres annually. It has increased by 12 percent over the period between the two FIA surveys.

Approximately 640,000 acres are thinned annually. This practice is most often used in pine plantations and on FI land, which account for 48 percent of the total thinned area. Considering the size of FI timberland area, this result indicates relatively high thinning intensity. The total thinned area increased by nearly 3 percent between the FIA surveys. The largest increases in thinning area of up to 74 percent occurred on FI and MC land. Thinning intensity decreased on PB land.

Table 14.2—Current status and trends in annual use of forest management practices by owner based on FIA data

Treatment	Public	Forest industry	Misc. corporate	Non-industrial private	Total	Change between FIA surveys
	- - - - - - - - - - -Thousand acres per year- - - - - - - - - - -					*Percent*
Clearcut	90.9	578.4	207.3	1,146.1	2,022.7	9.5
Partial cut	156.7	847.6	293.6	2,011.4	3,309.2	12.4
Thinning	52.0	306.0	65.9	219.0	642.8	2.5
TSI	189.5	382.0	65.1	304.9	941.5	74.4
Site prep.	66.0	633.6	104.6	378.6	1,182.7	1.0
Burning	440.8	833.7	195.6	818.4	2,288.5	-3.5
Planting	70.2	696.3	131.9	744.8	1,643.3	25.2
Natural regen.	89.4	264.2	152.1	1,195.7	1,701.5	18.0

TSI = timber stand improvement.

TSI operations are carried out on about 940,000 acres annually. This area has increased by about 74 percent between the FIA surveys. The largest increases also occurred on FI and MC land. Natural pine forests account for 39 percent of TSI land, and planted pine forests account for 30 percent.

Nearly 1.2 million acres are site-prepared annually. About 60 percent of site preparation is for pine planting. Much of the rest is for natural regeneration of pine. FI land accounts for 54 percent of site-prepared area. While site-prepared area has been relatively stable, there were some changes among ownership groups. MC owners increased site-prepared area by 56 percent, while PB and FI owners decreased their acreages of site preparation.

Burning is the only management practice that became less common. Currently, it occurs on nearly 2.3 million acres annually, primarily on FI and NIPF land. The total number of burned acres has decreased by nearly 4 percent. Burning is most frequent in natural and planted pine stands.

Annually, 1.6 million acres are planted, both for reforestation and afforestation. Planting rates have increased by 25 percent between the FIA surveys or about 3.6 percent per year. Pines dominate 75 percent of planted land. In addition, planted pines occur in oak-pine stands in which hardwoods make up over half of the stocking. Between the surveys, NIPF owners and MC owners have increased planting rates by 85 and 68 percent, respectively. Natural regeneration is practiced on nearly 1.7 million acres annually. Between FIA surveys, naturally regenerated area increased by 18 percent.

Nearly 1.6 million acres of planted pine were fertilized in 1999 (North Carolina State Forest Nutrition Cooperative 2000). The increase from 1990 is nearly 800 percent. Nearly 10 million acres were fertilized in the South since 1969. This area is estimated to exceed the sum of forest fertilization in the rest of the World taken together. While the exact distribution of fertilized land among forest owner groups is not available, the Forest Nutrition Cooperative data indicate that fertilization is primarily the domain of FI and TIMOS. Fertilization will likely become even more popular in the future as new, more intensive silvicultural systems are introduced. Assuming that we have about 34 million acres of planted pine that will be fertilized at least twice during the rotation, fertilized area could at least double from today's levels.

Data on herbicide application were not available, but some inferences can be made about the area on which it is practiced. Results of forest owner surveys, discussed in the following sections, indicate that herbicide is applied together with fertilizer in higher management regimes. These results, coupled with planted pine area estimates and the assumption of a 25-year rotation length, indicate that herbicide might be applied on about 2.0 million acres annually.

Overall, rapid increases in harvest rates, planting and natural regeneration, TSI, and chemical applications indicate increasingly intensive management of southern forests. Intensive forest management is practiced primarily in pine plantations, which account for most planting, site preparation, fertilizer application, and thinning.

Naturally regenerated forest types are managed less intensively than pine plantations. Thinning, TSI, and burning are most common in natural pine, followed by oak-pine. Between the FIA surveys, oak-pine stands experienced substantial increases in clearcutting (40 percent), partial cutting (48 percent), TSI (102 percent), site preparation (118 percent), and burning (29 percent). These increases may result to some extent from classifying planted pine stands with a larger hardwood component as oak-pine. Hardwood forests are managed primarily in natural stands. They account for most forest land that is harvested and naturally regenerated, which is conditioned on their extensive cover in the region. FIA results indicate that areas of clearcutting, partial cutting, TSI, planting, and natural regeneration increased moderately, while thinning, site preparation, and burning became less popular between the surveys.

FI and MC holdings are managed most intensively, and intensity of management has increased markedly. Management intensity of NIPF land is also increasing, but to a lesser extent. Management intensity on PB land, the smallest ownership category in the South, appears to be changing as well. Clearcutting, TSI, planting, and burning have increased. Partial cutting, thinning, site preparation, and natural regeneration have decreased.

Changes in stand structure (even-aged, two-aged, and uneven-aged) management are difficult to determine due to the lack of data. About 34 million acres of planted stands are in planted pine or oak-pine forest types. These stands are managed in even-aged systems. With few exceptions, the remaining stands were regenerated naturally. Depending on natural growth conditions, types of cutting, and other disturbances, they may represent any of three age structures. Implementation of uneven-aged management systems is quite complex, and many uneven-aged forests probably were not established intentionally. Some FI firms practice two-aged and uneven-aged silviculture in hardwood forests.

Effects of Various Forest Management Intensities on Productivity

Five management intensity classes (MICs) were developed to estimate potential pine growth and yield on FI land (Siry 1998, Siry and others 2001). MICs range from traditional planted pine management, consisting only of site preparation and planting, to more intensive approaches involving planting of genetically improved growing stock, fertilizer application, and herbicide application to control competing vegetation. MICs assumptions for unthinned and thinned stands are summarized in tables 14.3 and 14.4.

Genetically improved stock was assumed to increase volume by 14 percent at the culmination of mean annual increment (Siry 1998, Siry and others 2001). This increase corresponds to a 5-foot site index (SI) increase on medium sites (SI 60). The impact of 200 pounds of nitrogen and 25 pounds of phosphorus fertilizer was modeled by increasing yield by 400 cubic feet during the 5-year period after treatment. The impact of competing vegetation control on yield was modeled by increasing SI by 5 feet for MIC 4 and 7 feet for MIC 5.

Table 14.3—Southwide unthinned management scenarios[a]

Treatment/MIC	MIC1 traditional	MIC2 low	MIC3 medium	MIC4 high	MIC5 very high
First generation genetics	N/A by 14% at CMAI	Increase yield by 14% at CMAI	Increase yield by 14% at CMAI	Increase yield by 14% at CMAI	Increase yield CMAI
Fertilization (N and P)	N/A	N/A	Age 15	Age 15	Low: age 10, 15 Med.: age 8, 13 High: age 5, 10
Competing vegetation control	N/A	N/A	N/A	Increase SI by 5 ft	Increase SI by 7 ft

SI = site index; MIC = management intensity class; CMAI = culmination of mean annual increments.

[a] Planting density = 600 trees per acre; medium sites (SI = 60).

Table 14.4—Southeast and South-Central thinned management scenarios[a]

Treatment/MIC	MIC1 traditional	MIC2 low	MIC3 medium	MIC4 high	MIC5 very high
First generation genetics	N/A	Increase yield by 14% at CMAI	Increase yield by 14% at CMAI	Increase yield by 14% at CMAI	Increase yield by 14% at CMAI
Fertilization (N and P)	N/A	N/A	At time of thinning	At time of thinning	At time of thinning
Competing vegetation control	N/A	N/A	N/A	Increase SI by 5 ft	Increase SI by 7 ft
Thinning regime: Southeast	All sites: 1 thinning	All sites: 1 thinning	All sites: 1 thinning	All sites: 1 thinning	Low: 1 thinning; Med., High: 2 thinnings
Thinning regime: South Central	Low: 1 thin; Med., High: 2 thinnings	Low: 1 thin; Med., High: 2 thinnings	Low: 1 thin; Med., High: 2 thinnings	Low: 1 thin; Med., High: 2 thinnings	All sites: 2 thinnings

SI = site index; MIC = management intensity class; CMAI = culmination of mean annual increments.

[a] Planting density = 600 trees per acre; medium sites (SI = 60).

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In thinned stands, the impact of genetically improved growing stock and competing vegetation control was modeled in the same way as in unthinned stands. Fertilizer application was assumed to take place at the time of thinning. Thinning had to remove at least 450 cubic feet per acre of wood volume, which roughly corresponds to about 600 cubic feet per acre of gross volume (wood and bark). This volume was assumed to be the minimum for economically feasible thinning. Furthermore, thinning could not reduce the basal area of residual stands below 80 square feet per acre, ensuring that sufficient growing stock remained. For multiple thinnings, a 5-year time lag between thinning was specified to capture the full response from fertilizer. These thinning assumptions reflect management objectives to provide intermediate cash flows and increase production of higher quality sawtimber. Single thinning was assumed to prevail in the Southeast. In the South-Central region, multiple thinnings occurred in most cases.

Examples of planted pine yields by MICs and thinning regimes on medium sites are presented in figures 14.1, 14.2, and 14.3. Yields in unthinned stands vary at age 25 from about 2,700 cubic feet per acre for MIC 1 to nearly 4,600 cubic feet per acre for MIC 5. The difference of about 1,900 cubic feet per acre indicates that MIC 5 has the potential to produce almost 70 percent more volume that MIC 1. In unthinned stands, the largest increase in yield comes from controlling competing vegetation. That treatment increases yields by 600 cubic feet per acre for MIC 4 and 750 cubic feet per acre for MIC 5 at age 25. Genetic improvement increases yield by nearly 420 cubic feet per acre at age 25. Finally, as explicitly assumed, fertilization increased yield by 400 cubic feet per acre.

Yields in thinned stands vary at age 25 from about 1,900 cubic feet per acre for MIC 1 to 2,600 cubic feet per acre for MIC 5. Thinning removals for a single treatment range from nearly 500 cubic feet per acre to 800 cubic feet per acre. Thinnings produce primarily pulpwood, with the exception of MIC 5, where 35 percent of wood volume produced by the second thinning is sawtimber. Total yield (thinnings plus yield at age 25) ranges from about 2,400 cubic feet per acre for MIC 1 to nearly 3,900 cubic feet per acre for MIC 5. The difference of about 1,500 cubic feet per acre indicates that MIC 5 has the potential to produce 65 percent more volume that MIC 1 in thinned stands. More intensively managed stands were thinned earlier. The most pronounced yield increases resulted from competing vegetation control and fertilizer application. Fertilizing permitted earlier second thinning or increased volume in the thinning.

Thinning reduced total volume production throughout the rotations, because accelerated basal area growth of residual stands did not compensate for the loss of productive capacity removed in the thinning. The volume reduction ranged from 7 to 15 percent or from 230 cubic feet per acre to nearly 700 cubic feet per acre when compared with unthinned stands in the MICs at age 25. Thinning also shifted the diameter distribution to the right, implying that thinned stands grow less timber, but that its quality and value are higher. While the share of sawtimber in total volume in unthinned stands ranges from 32 to 48 percent at age 25, in thinned stands it ranges from 45 to 76 percent.

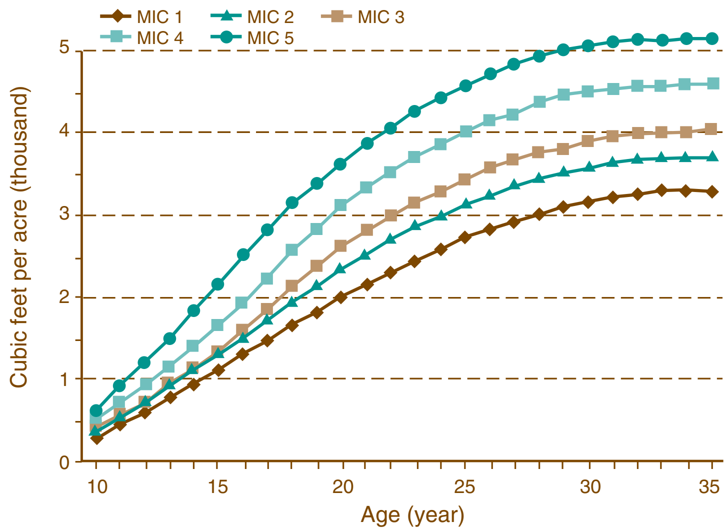

Figure 14.1—Planted pine yields, Southwide, unthinned. MIC is management intensity class.

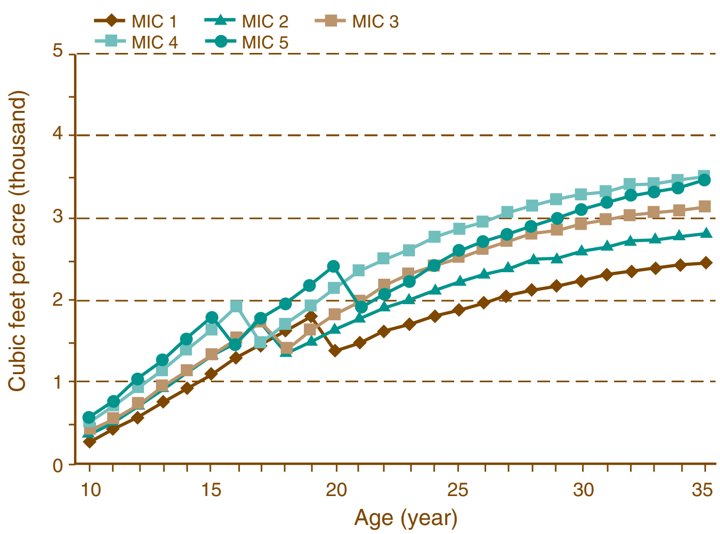

Figure 14.2—Planted pine yields, Southeast region, thinned. MIC is management intensity class.

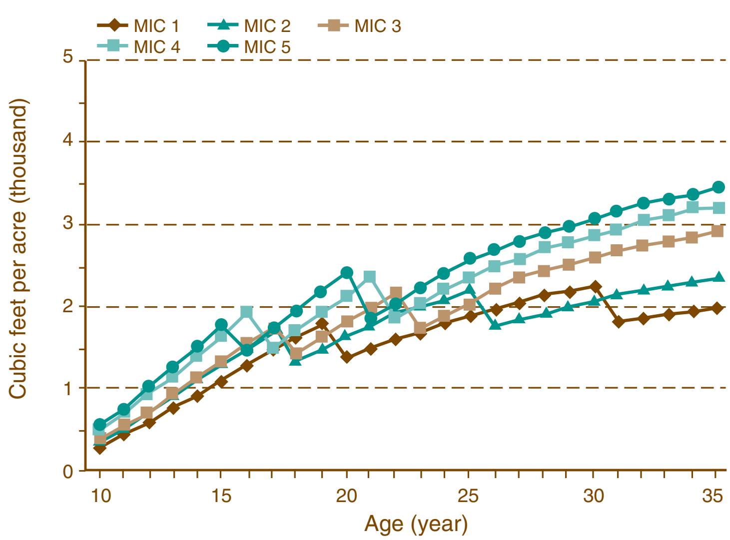

Figure 14.3—Planted pine yields, South-Central region, thinned. MIC is management intensity class.

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Table 14.5 compares unthinned planted pine yields by MIC on medium sites with empirical yields used by the Subregional Timber Supply (SRTS) model (Abt and others 2000) and the 1993 Resources Planning Act (RPA), and yields recorded in the 1997 FIA survey of Georgia. SRTS yields rely exclusively on empirical values developed directly from FIA data, while RPA yields rely on FIA data as well as on yield curves developed during past RPA assessments. This analysis of the planted southern pine growth and yield indicates that projected plantations yields are much higher than historical FIA data. Increases range from 15 percent (for MIC 1) to 94 percent (for MIC 5) above current SRTS empirical data for average sites at age 25. Projected yields are also greater than those used in the last RPA modeling efforts. Furthermore, projected yields, with the exception of the youngest age class, are consistently higher than yields from the most recent FIA Georgia survey.

In summary, intensified management of planted pine provides substantial opportunities for increasing timber growth, yield, and quality. Fertilizer increases yield by 400 cubic feet per acre per treatment; genetic improvement increases yield by nearly 420 cubic feet per acre; and competing vegetation control increases yield by up to 750 cubic feet per acre. These treatments applied together have the potential to exceed traditional yields (MIC 1) by 70 percent, and SRTS-FIA and the last RPA yields by nearly 100 percent.

Information about effects of various management intensities on natural forests productivity is limited. FIA-based empirical yields developed for the SRTS model indicate that average annual growth rates for natural pine across all sites can be as high as 86 cubic feet per acre, followed by oak-pine (54), upland hardwood (47), and bottomland hardwood (44) (Abt and others 2001, Siry and others 1999). These results also indicate that FI natural pine yields can be nearly 20 percent higher than NIPF yields. The estimated average annual growth rates in natural stands are lower than those of planted pine stands, which range from approximately 109 cubic feet per acre (MIC 1) to 183 cubic feet per acre (MIC 5).

Table 14.5—Comparison of TAUYIELD projected growth and yield data for unthinned MICs with FIA data and modeling assumptions. Merchantable wood volume (cubic feet per acre to a 4 in. diameter outside bark top)[a]

	Stand age				
MIC	10	15	20	25	30
	Cubic feet per acre				
MIC 1: traditional	309	1,121	2,004	2,716	3,158
MIC 2: genetics	396	1,353	2,355	3,135	3,605
MIC 3: MIC2+F	396	1,353	2,637	3,433	3,912
MIC 4: MIC3+H	518	1,670	3,139	4,033	4,502
MIC 5: MIC4 +2nd F&H	641	2,170	3,645	4,587	5,057
SRTS-FIA	568	1,138	1,708	2,361	3,013
1993 RPA	310	1,136	1,892	2,382	2,824
1997 FIA Georgia survey	420	912	1,540	1,969	2,625

MIC = management intensity class; F = fertilization; H = herbicide application.

[a] TAUYIELD assumes SI 60 at base age 25 and planting density is 600 trees per acre; SRTS-FIA, 1993 RPA, and 1997 FIA Georgia survey data are average for all sites.

In comparison with pine management, hardwood management in the South has been neglected. The range of active management approaches varies, but managed stands rarely achieve growth rates that are much higher than those in unmanaged natural stands (Robison and others 1998). Research results indicate that treatments including herbicide application, fertilization, enrichment planting, and thinning have the potential to substantially increase hardwood stand productivity (Groninger and others 1998; Lockaby and others 1997; Meadows and Goelz 1999a, 1999b; North Carolina State Hardwood Research Cooperative 2001).

The area of hardwood plantations is very small. It is estimated that there are about 200,000 acres of hardwood plantations in the South (Dvorak and others 1998). FI owns about 60,000 acres of hardwood plantation (Goetzl, A. March 23, 1998. AF&PA southern forest management intensity survey. Data summary and survey results. Unpublished report. On file with: American Forest and Pulpwood Association, Washington, DC). In addition, the industry established about 12,000 acres of hardwood plantations with short rotation intensive silviculture (SRIS). These plantations are managed on up to 12-year rotations. Management treatments include intensive site preparation, plantation of genetically advanced seedlings, complete competing vegetation control, and high-intensity fertilization. Genetic improvement increases yields by up to 25 percent per rotation.

Hardwood plantation establishment in many cases has been difficult and expensive. Earlier plantations had growth rates similar to natural hardwood stands, with the exception of cottonwood plantations along the Mississippi River (Robison and others 1998). Progress in genetic improvement, propagation, and silviculture appears critical for hardwood plantations to increase the production of high-quality and uniform wood. Hybrid poplar plantations in the South already can grow substantially more timber than natural hardwood stands (Alig and others 2000).

Quality of Forest Investments

Intensive management can greatly increase pine growth and yield, but the use will depend on financial returns. Six management-cost categories were included in the analysis based on a forest industry survey (Siry and others 2001). On average, it is assumed that site preparation costs $140 per acre. Seedlings and planting cost $70 per acre, and the use of genetically improved seedlings raises this cost to $75 per acre. Fertilization costs $50 per acre per treatment. Tax and administration expenses are $8 per acre annually. Assumed costs of herbicide application for MIC 4 are $50 per acre. The costs of the two herbicide treatments in MIC 5 are (1) weed control treatment at year zero for $35 per acre, and (2) woody plant control treatment at year three for $50 per acre. There are only three revenue categories, two timber and one non-timber. Thinnings primarily produce pulpwood; and the final harvest produces pulpwood and sawtimber, which generate $25 per cord and $350 per thousand board feet, respectively. Hunting leases are assumed to generate $3 per acre annually.

Basic financial measures commonly used in forestry—NPVs, SEVs, and IRRs for unthinned and thinned scenarios—are presented in table 14.6. These financial measures were calculated using a 6-percent real discount rate. In addition, a 1-percent annual timber price appreciation was factored in. Financial results were developed for rotations determined by SEV criterion.

In unthinned scenarios, NPVs vary from $440 per acre for MIC 1 to $990 per acre for MIC 5. Similar relationships apply to SEVs, which vary from $532 per acre for MIC 1 to $1,249 per acre for MIC 5. Real IRRs for the MICs vary from nearly 10 to 12 percent. These criteria indicate that intensified forest management generates positive and apparently attractive financial returns.

In thinned scenarios, NPVs vary from $411 per acre for MIC 1 to $1,082 for MIC 5. Similarly, SEVs vary from $504 per acre for MIC 1 to $1,411 for MIC 5. Real IRRs among the MICs vary from nearly 10 to 13 percent.

A comparison of the performance of unthinned and thinned scenarios indicates that IRRs for thinned scenarios are the same as or higher than IRRs for unthinned scenarios. IRRs reach the highest level of 13 percent in the MIC 5 thinned scenario. However, NPVs and SEVs for scenarios with one thinning are lower than for unthinned scenarios. Only multiple thinning scenarios for MIC 3 to MIC 5 generate higher returns than corresponding unthinned scenarios. Among all thinned and unthinned scenarios and management intensity classes, MIC 5, the most intensive multiple thinning scenario, generates the highest financial returns.

Natural hardwood stands can be managed with profit as well. Typically, such management relies on an even-aged system, clearcutting, and sorting harvested logs for the highest value market (Robison and others 1998). Naturally regenerated, even-aged hardwood stands were shown to generate positive rates of return comparable with planted pine (Thompson 1992). Hardwood afforestation also generates positive returns. Cottonwood afforestation projects in the Mississippi Valley were profitable under most conditions (Stanturf and Portwood 1999). Even-aged management appears well suited to intensive hardwood pulpwood production. Two-aged and multi-aged silviculture also have promise, but they are not practiced on a large scale, and conditions for uneven-aged silviculture generally are not favorable (Robison and others 1998).

Table 14.6—Summary of financial analysis of loblolly pine by MIC for medium sites (pulpwood $25 per cord, sawtimber $350 per thousand board feet) at 6-percent real discount rate[a]

MIC	Rotation	Yield	NPV	SEV	IRR
	Years	*Ft³/ac*	*$/ac*	*$/ac*	*%*
			Southwide unthinned		
SRTS-FIA	30	3,013	416	504	9.6
MIC 1	30	3,158	440	532	9.7
MIC 2	29	3,531	601	737	10.6
MIC 3	28	3,763	648	806	10.9
MIC 4	28	4,373	860	1,070	11.3
MIC 5	27	4,846	990	1,249	11.9
			Southeast thinned		
MIC 1	29	2,718	411	504	9.8
MIC 2	28	2,968	550	684	10.8
MIC 3	27	3,203	615	776	11.2
MIC 4	27	3,640	768	966	11.4
MIC 5	25	3,899	1,082	1,411	13.0
			South Central thinned		
MIC 1	29	2,718	411	504	9.8
MIC 2	28	3,429	564	702	10.9
MIC 3	27	3,514	782	987	12.1
MIC 4	26	3,847	1,043	1,337	12.9
MIC 5	25	3,899	1,082	1,411	13.0

MIC = management intensity class; NPV = net present value; SEV = soil expectation value; IRR = internal rates of return; SRTS = Subregional Timber Supply Model; FIA = Forest Inventory and Analysis, USDA Forest Service.

[a] Assumed 1 percent real annual timber appreciation.

To obtain more information about current and future forest management intensities, results of current surveys of FI, TIMOS, and NIPF land in the South were compared (Moffat and others 1998, Siry 1998, Siry and Cubbage 2001, Siry and others 2001). The surveys provide information about the current and future allocation of forest land among forest types, management intensities, and conversion to planted pine. Table 14.7 summarizes these results.

Planted pine management is described for three management intensities: standard management, superior management, and high-yield management. Standard management involves chemical or mechanical site preparation followed by planting. Superior management involves more intensive site preparation, genetically improved growing stock, woody plant control if needed, and mid-rotation fertilizer application to about 50 percent of the land. Finally, high-yield management adds herbicide application in the first and second growing seasons and fertilizing of half of the land at age 8.

Custodial even-aged management is applied in natural pine, oak-pine, and upland and bottomland hardwood stands. Generally, no treatments are made and none are planned. Higher intensity management consists of some actions, such as fertilizing or thinning, carried out in even-aged stands. When planted pine, natural pine, and oak-pine stands are harvested, plantations are established on a percentage of the harvested areas.

Since the surveys used varying definitions and management categories, their results are not exactly comparable. Assumptions had to be made about merging FI management-intensity classes into three classes common to all surveys and owner categories and adjusting the results to common time periods. This limitation needs to be recognized while interpreting the results.

Planted pine accounts for about 65 percent of FI and TIMOS holdings. During the next two decades, the share of planted pine is expected to increase to about 80 percent. This expansion comes primarily at the cost of natural pine.

Upland hardwoods occupy about 40 percent of NIPF land. During the next two decades, upland hardwoods' share is expected to decrease to 35 percent. Planted pine is expected to increase from the current 10 to 14 percent.

FI and TIMOS have up to 5 percent of their land reserved from harvest. This category comprises land where timber will not be commercially utilized or processed in the foreseeable future due to particular landowner preferences, regulatory constraints, or other reasons. During the next two decades the share of reserved FI and TIMOS land is expected to remain

Table14.7—Summary results of forest management surveys by ownership group and yearw

Management category	Forest industry 2000	Forest industry 2020	TIMO 2000	TIMO 2020	Nonindustrial private 2000	Nonindustrial private 2020
	Percent forest land area					
Land distribution						
Planted pine	63	81	69	81	10	14
Natural pine	11	2	9	3	14	10
Oak-pine	4	2	2	1	14	13
Upland hardwood	6	1	3	1	40	35
Botttomland hardwood	12	11	9	8	14	12
Not stocked	1	1	3	1	1	1
Reserved	3	2	5	5	7	15
Management intensity						
Planted pine						
Standard	14	2	6	2	11	8
Superior	46	25	38	28	64	46
High yield	40	73	56	70	25	46
Natural pine						
Lower	61	71	59	40	79	52
Higher	39	29	41	60	21	48
Oak-pine						
Lower	95	95	75	73	85	76
Higher	5	5	25	27	15	24
Upland hardwood						
Lower	97	89	95	82	91	86
Higher	3	11	5	18	9	14
Botttomland hardwood						
Lower	91	81	93	81	88	76
Higher	9	19	7	19	12	24
Conversion to planted pine						
Planted pine		78		84		32
Natural pine		13		12		12
Oak-pine		7		4		32
Other		2		0		24

TIMO = Timberland Investment Management Organization.

unchanged; the share of NIPF reserved land is expected to roughly double to 14 percent. The amount of nonstocked land is uniform among the three ownerships and equals about 1 percent.

The growing share of planted pine is accompanied by more intensive management. While today FI and TIMOS manage from 40 to 56 percent of their planted pine in a high-yield management regime, as much as 70 percent will be so managed in 20 years. NIPF planted pine is managed less intensively. Today only a quarter of planted pine is managed in a high-yield regime, but this share is expected to increase to nearly 50 percent during the next two decades.

Natural pine, oak-pine, and hardwood forest types are managed with lower intensity than planted pine. During the next two decades, natural pine, oak-pine, and bottomland hardwood management intensities are expected to increase only moderately.

Results indicate that intensive forest management offers attractive financial returns and that planted pine management will be increasingly important. Forest management will be characterized by more widespread planting of genetically improved seedlings, application of herbicide and fertilizer, thinning, and clearcutting. These treatments increase timber growth and quality, which will shorten rotations by up to 5 years. Intensified management of natural and planted hardwood stands also has the potential for attractive returns.

Multiple-Use Intentions and Outcomes on Private Land

Private forests provide a wide range of uses and benefits, including timber, watershed maintenance, soil retention, range potential, wildlife habitat, and recreation opportunities. Timber production and nontimber uses are linked in several direct and indirect ways. Timber growing may increase some nontimber benefits, decrease others, or replace existing uses with different ones (Rudis 1988). The multitude of management objectives and ways to achieve them make it difficult to determine the multiple-use intentions of private landowners. Linking multiple-use intentions and outcomes also is difficult because forests managed exclusively for a single use, such as timber growing, still support a range of nontimber benefits.

Industrial owners, FI and TIMOS, manage their land primarily for timber. Despite timber management's predominance, nontimber uses are recognized in forest management through best management practices. In the end, these industrial forests produce timber while supporting a range of nontimber uses.

NIPF owners are much less uniform in their approaches to forest management. They have multiple objectives, and their actions are far more complex than industrial owners (Conway and others 2000, Dennis 1989, Klein and others 2000, Newman and Wear 1993, Swallow and Wear 1993). Their management approaches range from very intensive management, similar to FI and TIMOS, to an entire disregard of forest management. NIPF owners who value nontimber benefits are less likely to manage their forests for timber production if it reduces these uses. NIPF owners may extend rotations if nontimber services increase with forest age and volume.

Certainly, timber is an important reason for ownership, as is improving the value of land. A comparison of industrial and nonindustrial owners indicates that the behavior of both groups is consistent with profit motives behind forest management (Newman and Wear 1993). But NIPF owners capture significant nontimber benefits, and their behavior differs from FI. They produce proportionally less softwood than their land share would indicate.

Nearly 45 percent of private owners in the South have harvested timber on about 78 percent of forest land (Birch 1997). Owners of 60 percent of forest land plan to harvest timber within 10 years, and owners of only 12 percent of southern forest land declare that they will never harvest. This outcome also indicates that private owners holding most timberland in the region respond to economic incentives and harvest timber at some point in time (Sampson and DeCoster 1997).

Overall, there are about 5 million forest owners in the South (Birch 1997). While corporate owners, which include FI and TIMOS, constitute only 1 percent of all southern owners, they manage nearly 30 percent of southern forests. Nearly 4.7 million NIPF owners manage about 60 percent of southern forest land. Their management intentions depend on personal objectives and financial constraints, which can be inferred from certain characteristics, such as tract size, occupation, and income.

The average size of NIPF forest holding is quite small (Birch 1997). Two-thirds of NIPF tracts are smaller than 10 acres, and three-quarters are smaller than 20 acres. Owners of these small tracts control about 12 percent of forest land in the South. The small size of tracts makes regular forest management more difficult. Small tracts, for example, may be characterized by higher harvesting costs (Comolli 1981). Small tracts, therefore, are associated with lower removals and planting rates (Thompson 1997, 1999; Thompson and Johnson 1996). This forest land is also less likely to be intensively managed for timber in the presence of substantial nontimber benefits. Major purposes of ownership include a place of residence, farming, recreation, and investment (Birch 1997). For a majority of NIPF owners, their forest is a part of their residence, but absentee owners also are common.

Progressing forest fragmentation may have some impact on regional timber production and nontimber uses. Between 1978 and 1994, the number of tracts smaller than 10 acres increased by 50 percent (Birch 1997). The number of new forest owners is expected to increase, and more forest land may be managed less for timber production and more for nontimber uses (Sampson and DeCoster 2000). Moreover, it also is possible that landscapes composed of many small owners with diverging objectives will make the achievement of nontimber uses ranging from wildlife to recreation increasingly difficult.

The shift towards more intensive management and pine plantations raises concerns about nontimber uses and values. Regional impacts of these trends are hard to determine because of the complexity of possible interactions. Pine plantations are criticized for low diversity, increasing herbicide use, and large even-aged stands that provide fewer opportunities for recreation, beauty, and wildlife. These negative outcomes can, to some extent, be mitigated by practicing thinning, prescribed burning, and partial harvesting, extending rotations, reducing herbicide use, and limiting plantation size, while promoting irregular boundaries (Allen and others 1996). Some of these approaches, however, may decrease the efficiency of timber production.

Still, plantations provide nontimber benefits and may even increase their overall provision if, for example, they are established on highly erodible agricultural land. In order to fully assess their impact on nontimber products and benefits, one must consider alternative uses, adjacent land uses, and site-specific needs for nontimber benefits. Today, pine species do not dominate any ecological province in the South (Rudis 1998). It is unlikely that they will ever dominate the region, even though planted pine area is expected to grow because of economic and environmental constraints that will eventually limit their expansion.

Forest owner surveys indicate that approximately 66 million acres are managed primarily for timber, 92 million acres are managed for a range of timber and nontimber uses, and 22 million acres are managed primarily for nontimber uses (Birch 1997, Moffat and others 2001, Siry 1998, Siry and Cubbage 2001, Siry and others 2001). Forests managed primarily for timber still support a range of nontimber uses. Forests managed for nontimber uses probably will produce less timber, but some management actions taken to enhance nontimber uses may produce some timber. Depending on circumstances, planted pine may either reduce or increase the provision of nontimber benefits. In order to determine net effects of increasing planted pine area on nontimber benefits, conditions across other forest types and owner groups throughout the region must be considered. It is apparent that the number of small forest tracks will grow in the future. This trend can make management for timber and nontimber products and uses more difficult.

No Active Management

Land is placed in the no active management category if no management actions, including timber harvest, are taken at present; and none are planned in the future. The determination of the area that is not actively managed presents similar problems to the estimation of multiple-use management intentions and outcomes. Most forests in the South were managed in some way in the past. Results of surveys of forest owners show that 10 million acres have been removed from timber cutting (Moffat and others 2001, Siry 1998, Siry and Cubbage 2001, Siry and others 2001). This amount is predicted to increase to nearly 20 million acres in the next two decades. Birch (1997) estimated that owners of about 22 million acres of forest land have no harvest intentions, but some other treatments may be applied.

Another evidence of forest management activities is the extent to which owners have a written management plan. Birch (1997) finds that such written management plans were reported by only 5 percent of owners, but that those owners hold 40 percent of private forest land. Written management plans were primarily prepared for tracts larger than 5,000 acres. While the lack of a written management plan does not indicate the lack of management activities, it implies that some land is managed quite extensively.

Given the limited evidence, it is concluded that about 10 million acres of private forests in the South get no active management. Forest owner surveys and continued forest fragmentation suggest that this area will increase over the next two decades to about 20 million acres.

Impact of Forestry Incentives Programs

Current and past forestry incentives programs have focused primarily on providing assistance to NIPF owners in tree planting, management planning, and improving forest management practices. They have increased timber production, investment returns, and environmental benefits.

The Forest Incentive Program (FIP), a Federal cost-share program enacted in 1973, was aimed at increasing timber supply by promoting tree planting, timber stand improvement, natural regeneration, and firebreak construction (Gaddis and others 1995). From 1974 through 1992, the program's cost-share incentives exceeded $200 million in the South and funded tree planting on nearly 2.5 million acres (40-percent increase), timber stand improvement on 0.3 million acres, and site preparation on nearly 10,000 acres. The program was most intensively implemented in the 1970s. In the 1980s and early 1990s, inflation increased treatment costs and reduced real FIP appropriations. The program was terminated in 1995. Timber supply was predicted to increase by 1 billion cubic feet each year due to the program (Gaddis and others 1995). The program was characterized by retention reaching 90 percent. It generated rates of return of about 10 percent.

The Forest Stewardship Program (FSP) and the Stewardship Incentives Program (SIP) were authorized in 1990 to replace FIP. FSP is operated in cooperation with State forestry agencies and assists in enhancing and protecting multiple forest values on NIPF land by developing forest management plans (New and others 1997). From 1990 to 1994, FSP developed 13,000 forest management plans covering 2.5 million acres in the South. FSP cost sharing amounted to $27 million. By 2000 FSP management plans were primarily developed and implemented for growing trees, improving wildlife habitat, harvesting trees, and improving water resources (Esseks and Moulton 2000). About 80 percent of prepared plans in the South were being implemented.

An FSP-approved forest management plan is a prerequisite for cost-share support under SIP. From 1992 to 1994, SIP in the South provided nearly $9 million in support for 4,000 owners with nearly 0.5 million acres (Gaddis and others 1995). The majority of funding was spent on tree planting activities. SIP and FIP supported tree planting on nearly 0.5 million acres in the South.

The Forest Legacy Program (FLP) is a Federal program aimed at environmental protection (Sampson and DeCoster 1997). FLP was designed to protect environmentally sensitive and valuable forest areas that are threatened by conversion to nonforest uses. This program supports State and Federal efforts through direct acquisition and conservation easements purchased from NIPF owners. The Rural Forest Management Program (RFMP) provides matching funds to State agencies to support their technical and financial assistance programs for conservation planting on NIPF land (U.S. Department of Agriculture Forest Service 2001).

State forestry assistance programs provide numerous services, including timber marketing, firebreak construction, forest management planning, forest seedlings sales, rental or loan of equipment, and literature and educational videos (Cubbage and Haynes 1988). Some States also enacted incentives programs. Expenditures for State cooperative forestry and landowner assistance programs in the South amounted to nearly $52 million in fiscal year 1998 (National Association of State Foresters 2001).

Forest industry firms also provide technical assistance to NIPF owners (Cubbage and Haynes 1988). Assistance ranges from forest regeneration to timber stand improvement and harvesting. These programs often require that tracts be of a minimum size and within a maximum distance from the mill. Land management practices are often performed for free or at a reduced cost to NIPF owners. Forest industry firms that offer these programs include, for example, Georgia Pacific (Forest Management Assistance Program), Stone Container Corporation (Land Owner Assistance Program), Louisiana-Pacific Corporation (Tree Enterprise Program), and Rayonier (Landowner Assistance Management Program) (Thompson 1995).

Overall, the majority of forestry incentives programs have promoted tree planting and more intensive forest management, better marketing of forest products, improved protection of existing resources, and enhanced planning. They have resulted in substantial increases in tree planting and more widespread development of forest management plans. The results and returns are generally satisfactory. Some critics have argued that these programs simply substitute public funds for private funds that would be invested in any case. While some capital substitution is possible, forestry incentives programs undoubtedly have resulted in substantially increased inventories and future timber supplies (Gaddis and others 1995, Lee and others 1992, New and others 1997).

TIMBER

Discussion and Conclusions

Timber management in the South has changed substantially over the past few decades, and current trends indicate that change will continue. As some forest owners adopt more intensive forest management, the production potential of forests increases accordingly. Genetic improvement of trees and intensified application of fertilizer, herbicide, and thinning will rapidly increase growth and yield of southern pines as well as shorten rotations. These benefits have important implications for long-term timber supply.

The South will increase softwood production using existing management technologies. By applying known technologies on a large scale, the South can almost double softwood growth rates. These higher management intensities are projected to be widely applied on FI and TIMOS land and even NIPF land. As a result, the South may be able to better meet increasing harvest demands than previously thought. Effects depend on the number of acres devoted to intensive management and on economic feasibility of intensive management. The economic analysis indicates that intensive forest management offers attractive returns.

These results, however, must be interpreted cautiously. It will be necessary to accurately model market adjustments to such changes. Higher growth rates will moderate price increases and thus reduce returns on investments in timber growing. Future supply increases could, therefore, be reduced. Furthermore, rapidly growing pine plantations can provide wood fiber, but quality and grade questions still must be considered. Questions about lumber quality, needs for pruning, ability to make reconstituted fiber products, and other factors still need to be addressed. And the technical properties of fast-grown planted pine need to be determined and milling and marketing adjustments made.

Finally, the results presented here apply mostly to southern pines. At present, it is not really known to what extent southern hardwood production might be increased through intensive management. In comparison with planted pine management, intensive hardwood management in the South has been neglected. Vast and available hardwood resources of lower value than pine have discouraged investments in intensive hardwood management. Further, most hardwood forests belong to NIPF owners, who do not generally support the development of industry-like approaches. Furthermore, with more than 40 commercial species in southern hardwood forests, silviculture there is complex. To date, active hardwood management has yielded only small increases in natural stand productivity and mixed results in plantations. Recent hardwood research results suggest, however, that substantial productivity increases are possible in both natural and planted stands. But they rely on progress in silviculture, genetic improvement, and clonal forestry. While these results are promising, much effort is still required to develop effective and widely applicable hardwood technology that is comparable with southern pines technology. Dwindling hardwood resources and changing market conditions may provide the required stimuli.

Needs for Additional Research

Additional research is needed to better assess the status and trends of forest management practices in the South. More work also is needed to better assess rotation lengths and particular stand structures (even-aged, two-aged, and uneven-aged). Additional effort is required to better evaluate the impacts of increasing planted pine yields. First, planted pine acreages and management intensities need to be determined. Productivity increases will likely moderate timber price increases and reduce investment incentives. It is necessary to accurately model market adjustments to such changes. In comparison with planted pine, hardwood research in the South has been neglected. Most pressing needs include research into productivity improvements in natural and planted stands from treatments, such as weed management, other silvicultural operations, genetic improvement, and clonal forestry. More research is also needed to determine multiple-use objectives and outcomes of forest management in the South, especially on NIPF land.

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Literature Cited

Abt, R.; Cubbage, F.; Pacheco, G. 2000. Southern forest resource assessment using the subregional timber supply (SRTS) model. Forest Products Journal. 50(4): 25–33.

Alig, R.; Adams, D.; McCarl, B. [and others]. 2000. Economic potential of short-rotation woody crops on agricultural land for pulp fiber production in the United States. Forest Products Journal. 50(5): 67–74.

Allen, A.; Bernal, Y.; Moulton, R. 1996. Pine plantations and wildlife in the Southeastern United States: an assessment of impacts and opportunities. Inform. Tech. Rep. 3. Washington, DC: U.S. Department of the Interior, National Biological Service. 32 p.

Amateis, R.; Radtke, P.; Burkhart, H. 1995. TAUYIELD: a stand growth and yield model for thinned and unthinned loblolly pine plantations. Rep. 92. Blacksburg, VA: Virginia Polytechnic Institute and State University, Loblolly Pine Growth and Research Cooperative. 38 p.

Birch, T. 1997. Private forest land owners of the Southern United States. Resour. Bull. NE–138. Randor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 195 p.

Comolli, P. 1981. Principles and policy in forestry economics. Bell Journal of Economics. 12: 300–309.

Conway, C.; Chapman, S.; Amacher, G. [and others]. 2000. Differences in nonindustrial landowner behavior between hardwood and pine regions of Virginia: implications for timber supply. SOFAC Rep. 19. Research Triangle Park, NC: Southern Forest Resource Assessment Consortium. 49 p.

Cubbage, F.; Haynes, R. 1988. Evaluation of the effectiveness of market responses to timber scarcity problems. Marketing Res. Rep. 1149. Washington, DC: U.S. Department of Agriculture, Forest Service. 87 p.

Dennis, D. 1989. An economic analysis of harvest behavior: integrating forest and ownership characteristics. Forest Science. 35(4): 1088–1104.

Dvorak, W.; Hodge, G. 1998. Wood supply strategies in countries with fast-growing plantations. PaperAge. March. [Number of pages unknown].

Esseks, J.; Moulton, R. 2000. Evaluating the forest stewardship program through a national survey of participating forest land owners. DeKalb, IL: Northern Illinois University, Center for Governmental Studies. 113 p.

Gaddis, D.; New, B.; Cubbage, F. [and others]. 1995. Accomplishments and economic evaluations of the forestry incentives program: a review. SCFER Work. Pap. 78. Research Triangle Park, NC: Southeastern Center for Forest Economics Research. 52 p. + app.

Groninger, J.; Stein, H.; Zedaker, S. [and others]. 1998. Growth response and cost comparisons for precommercial thinning methods of Appalachian oak stump sprout clumps. Southern Journal of Applied Forestry. 22(1): 19–23.

Kline, J.; Alig, R.; Johnson, R. 2000. Fostering the production of nontimber services among forest owners with heterogeneous objectives. Forest Science. 46(2): 302–311.

Lee, K.; Kaiser, F.; Alig, R. 1992. Substitution of public for private funding in planting southern pine. Southern Journal of Applied Forestry. 16(4): 204–208.

Lockaby, G.; Clawson, R.; Baker, T. 1997. Response of three hardwood species to irrigation and fertilization on an upland site. Southern Journal of Applied Forestry. 21(3): 123–129.

Meadows, J.; Goelz, J. 1999a. Thinning in a 28-year-old water oak plantation in north Louisiana: 7-year results. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 98–102.

Meadows, J.; Goelz, J. 1999b. Third-year growth and bole quality responses to thinning in a red oak-sweetgum stand on a minor streambottom site in west-central Alabama. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 87–93.

Moffat, S.; Cascio, A.; Sheffield, R. 1998. Estimations of future forest management intensity on NIPF lands in the South: results of the Southern State Forester's survey. SOFAC Rep. Research Triangle Park, NC: Southern Forest Resource Assessment Consortium. 7 p. + app.

National Association of State Foresters. 2001. Fiscal year 1998 State forestry statistics: financial resources in the State. [Database]. http://www.stateforesters.org/statistics/FY98_Statistics/Financial.htm. [Date accessed: July 4, 2002].

New, B.; Cubbage, F.; Moulton, R. 1997. The stewardship incentive program, 1992–1994: an accomplishment report and program review. SCEFER Work. Pap. 83. Research Triangle Park, NC: Southern Center for Forest Economics Research. 32 p. + app.

Newman, D.; Wear, D. 1993. Production economics of private forestry: a comparison of industrial and nonindustrial forest owners. American Journal of Agricultural Economics. 75: 674–684.

North Carolina State Forest Nutrition Cooperative. 2000. Twenty-ninth annual report. Raleigh, NC: North Carolina State University. 20 p.

North Carolina State Hardwood Research Cooperative. 2001. Thirty-eighth annual report 2001. Raleigh, NC: North Carolina State University. 62 p.

Robison, D.; Goldfarb, B.; Li, B. 1998. Advancing hardwood production forestry. PaperAge. May. [Number of pages unknown].

Rudis, V. 1988. Nontimber values of Louisiana's timberland. Resour. Bull. SO–132. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 27 p.

Rudis, V. 1998. Regional forest resource assessment in ecological framework: the Southern United States. Natural Areas Journal. 18: 319–332.

Sampson, N.; DeCoster, L. 1997. Public programs for private forestry. Washington, DC: American Forests. 100 p.

Sampson, N.; DeCoster, L. 2000. Forest fragmentation: implications for sustainable private forests. Journal of Forestry. 98(3): 4–8.

Siry, J. 1998. Southern plantation pine yield tables. SOFAC Rep. Research Triangle Park, NC: Southern Forest Resource Assessment Consortium. 5 p. + app.

Siry, J.; Cubbage, F. 2001. A survey of timberland investment management organizations forestland management in the South. SOFAC Work. Pap. Research Triangle Park, NC: Southern Forest Resource Assessment Consortium. 5 p.

Siry, J.; Cubbage, F.; Abt, R. [and others]. 1999. Southern growth and yield models and analyses. SOFAC Res. Rep. 16. Research Triangle Park, NC: Southern Forest Resource Assessment Consortium. 13 p. + app.

Siry, J.; Cubbage, F.; Malmquist, A. 2001. Potential impact of increased management intensities on planted pine growth and yield and timber supply in the South. Forest Products Journal. 51(3): 42–48.

Stanturf, J.; Portwood, J. 1999. Economics of afforestation with eastern cottonwood (*Populus deltoides)* on agricultural land in the Lower Mississippi Valley. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 66–72.

Swallow, S.; Wear, D. 1993. Spatial interactions in multiple-use forestry and substitution and wealth effects for the single stand. Journal of Environmental Economics and Management. 25: 103–120.

Thompson, L. 1995. Technical assistance available to CRP forest landowners. [Leaflet]. [Macon, GA]: Georgia Forestry Commission. [Not paged].

Thompson, M. 1997. A forested tract-size profile of South Carolina's NIPF landowners. Res. Pap. SRS–2. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 9 p.

Thompson, M. 1999. A forested tract-size profile of Florida's NIPF landowners. Res. Pap. SRS–15. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 10 p.

Thompson, M.; Johnson, T. 1996. A forested tract-size profile of Virginia's NIPF landowners. Res. Pap. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 8 p.

Thompson, T. 1992. Risk and return from investments in pine, hardwoods, and financial markets. Southern Journal of Applied Forestry. 16(1): 20–24.

U.S. Department of Agriculture, Forest Service, State and Private Forestry, Cooperative Forestry. 2001. Rural forest management program. http://www.fs.fed.us/spf/coop/ rfm.htm. [Date accessed: July].

How might existing and new technologies influence forest operations and the resultant conditions of forests?

Chapter 15: Forest Operations Technology

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Key Findings

- A wide range of technology is available for forest management in the South.
- New technology makes forest operations more productive, cost-effective, and environmentally sensitive.
- Increases in forest operations productivity and the logging workforce are being used to meet the increasing demand for fiber and to reduce unit production costs.
- Southern forests are generally managed under economic constraints. Choices of rotation length, systems, and operations technology are fundamentally determined by the costs and values of a selected management regime.

Introduction

Forest operations include regeneration harvests, thinning, pruning, timber stand improvement, site preparation, planting, prescribed fire, vegetation control, and fertilization. The methods, materials, and systems used to transform the forest are the technology of forest operations.

Forest operations are designed to meet management needs. For example, ecological requirements for natural regeneration in a particular forest type may include certain light levels, soil conditions, and seed-source spacing. These ecological requirements translate into the prescription for the forest operation. For example, the stand must be opened up to a certain density; stems must be selectively removed based on size, species, and spacing; and the soil litter layer should be disturbed for seed catch, but not compacted. These requirements define the technology that is needed to meet management objectives. Forest operations technology is also shaped by the requirements of forest industry. Product form from the woods must be compatible with the handling equipment at the receiving mill. Minimum specifications, such as small-end diameter, define the way trees are cut to length. Developments in forest products transportation, mill processes, and products affect the requirements of forest operations. Changes in the forest products industry may lead to new constraints or opportunities for work in the woods.

Available technology defines the possibilities of forest management and forest products by limiting the feasibility of operations. Generally, forest operations are limited by terrain, piece size, productivity, or costs. Increased effort (longer distances, handling more pieces, steep slopes, wetter ground) translates into greater cost per unit of production or per acre. The fundamental question facing the forest manager is whether the prescribed operation is both technically and economically feasible.

The current condition of southern forests, in part, reflects forest operations technology of the past. The mosaic of managed and unmanaged forested areas is partially a result of the technical and economical limits of previous forest operations. The network of roads and skidtrails on the forested landscape resulted in part from limitations on extraction distance and terrain. Stand composition of regenerated acres reflects the past site preparation and stand establishment techniques. Similarly, future landscapes of southern forests will be an expression of the capabilities and limitations of today's technology. Understanding the role of technology in shaping forest conditions will help predict the future of the southern forest resource.

This chapter documents current southern forest operations and describes the interaction among forest operations technology, management practices, and forest condition.

Methods

Descriptive data in this chapter were generally obtained through standard literature review methods. The evaluation of logging workforce productivity, however, involved some additional data analysis. County-level employment data from the 1990 Census were merged with 1995 county-level timber products output data. Total logging employment was assumed to be relatively constant from 1990 to 1995 based on employment data from the Annual Survey of Manufactures (ASM). Timber product output in thousand cubic feet and logging employment were aggregated by ecological section. Annual productivity per logger was calculated at the ecological section level. The geographic distribution of logging workers was examined by combining county-level logging employment with total county land area to arrive at logging workers per 100 square miles. Finally, analysis of variance was used to examine variation in aggregate logging productivity as a function of percent pulpwood and percent hardwood in the section.

Data Sources

While most of the information for this chapter is derived from conventional literature sources, online databases were utilized to estimate workforce and productivity. The primary source of county-level timber product output (TPO) data was the Forest Inventory and Analysis (FIA) TPO Database Retrieval System (Anonymous 2000). This database contains information about roundwood products harvested in each county for calendar year 1996, by species and product class.

There are several sources of logging employment data. County-level data were obtained from civilian labor force data of the 1990 decennial census (U.S. Census Bureau 2000b), the most recent available sample of self-reported employment status. A sample of 1990 Census respondents described their industry and occupation. Based on this information, people were assigned to standard occupational and industry codes. Total logging employment was assumed to consist of both occupations 496 (Timber cutting and logging) and 494 (Supervisors, forestry, and logging). State-level logging employment data for the period 1997 to 1999 were derived from the Covered Employment and Wages Program (ES-202) of the Bureau of Labor Statistics (U.S. Department of Labor, Bureau of Labor Statistics 2000a). The ES-202 data are a 100-percent report for all establishments covered by unemployment compensation insurance. Older state-level workforce data were compiled from the ASM (U.S. Census Bureau 2000a). ASM data are collected through a mail survey of a sample of establishments. Both the ES-202 and ASM were queried for total state-level employment in Standard Industrial Classification (SIC) Code 241, Logging. Some years of the ASM data are missing for Kentucky, Tennessee, and Oklahoma.

The 1990 Census provides a snapshot of logging employment at the county level. Because it is based on self-reported occupation, it may provide a more accurate measure of workforce in an industry with many small firms and self-employed workers. However, it is also subject to errors in classification, and some nonloggers are likely included in the 494/496 occupational codes. The annual data from the ES-202 and ASM surveys provide an employment time series, but likely underestimate the logging workforce because they are based on a sampling of establishments. A comparison of the 1990 workforce at the county and state-level highlights the possible disparity. The ASM data estimate a total southern (less Kentucky, Tennessee, and Oklahoma) logging workforce of 36,000. In comparison, the decennial census estimates a total of 44,066. Most States are within several hundred workers. Texas, Virginia, and Mississippi, however, account for 6,000 of the 8,066 difference in workforce estimates. For this report, the decennial census data were considered a reasonable estimate of workforce and the manufacturer survey data were used to model trends over time.

Results

Description of Forest Operations Technology

Forest management requires a range of tools to implement prescriptions from planting, fertilization, burning, and herbicide application, through thinning and product extraction. International Standard 6814 (ISO 1999) provides common definitions for individual machines. In many management activities, however, the individual machines are grouped into systems. A forest operation system is more than technology represented in equipment design. A system includes the technology of methods and human work. While the capabilities of individual machines are of interest, the overall productivity and impacts of operations are the result of the cumulative effect of systems.

Technology for site preparation and establishment—Site preparation and stand establish-ment operations may require seedbed preparation, reduction of competition, alteration of soil moisture or physical properties, or nutrient amendment.

The desired management objectives are to control stocking, species composition, survival, or growth. Given the wide range of sites and objectives in the South, there are many operations that can be employed. Since 1952, a periodic survey of southern forest land managers has been conducted to estimate the prevalence and costs of forest management practices (Dubois and others 2001). Fifty-four percent of the responses to the most recent edition of the "Cost Trend Survey" were from forest industry, 32 percent from consultants, and 14 percent from public agencies.

Prescribed fire is the least expensive way to prepare the forest floor for regeneration. It provides some control of herbaceous competition, exposes mineral soil for seed catch, and reduces logging debris. Prescribed fire is used in prescriptions for natural regeneration by the seed-tree, single-tree selection, and shelterwood systems, as well as for artificial regeneration. Waldrop (1997), for example, describes the use of manual felling combined with fire to regenerate pine-hardwood stands in the Southern Appalachians. Fire often controls hardwood growth enough to allow pines to become established. While regeneration is an important use of fire, the "Cost Trends Survey" found the most common use of fire (about one-third of treated acres) is to reduce hazardous accumulations of fuels at mid-rotation.

Like prescribed fire, chemical treatment is used to control vegetative competition for light, moisture, and nutrients. Forestry herbicides can be applied by stem injection, soil application, or foliar spray. Busby and others (1998) compared herbicide treatment at stand establishment with early release applications and found that herbicide application at stand establishment had the greatest economic returns. Groninger and others (1998) describe the effectiveness of herbicide injection for precommercial thinning of oak stump sprouts. The "Cost Trends Survey" found that about one-fourth of the treated acres were by aerial application at the time of stand establishment. Another third were chemically treated to achieve early release or herbaceous weed control. The reported costs of herbicide treatment were about four times those for prescribed fire ($68 versus $18 per acre).

Mechanical site preparation is designed to modify soil conditions, clear planting sites, and control competing vegetation. Each type of operation addresses specific site conditions. Drum chopping, for example, knocks down standing material and breaks it into pieces using large rolling cylinders fitted with blades. In shearing, an angled blade on the front of a crawler tractor splits stumps, moves debris, and exposes mineral soil. Raking also uses a special blade on a crawler tractor to move and pile slash. Surface soil can be disked to reduce vegetative competition. Bedding loosens and moves soil to create raised planting areas. Finally, subsoiling or ripping fractures heavy or compacted soils. Site preparation prescriptions may call for a single type of treatment or a combination of treatments. According to the "Cost Trends Survey," the most common treatment in the Piedmont is a combination of subsoiling, disking, and bedding accomplished in a single pass with a 3-in-1 plow ($121 per acre). This tool was developed around 1990 to reduce site preparation costs. On the Coastal Plain, a multipass treatment combining shearing, raking, and piling is the most common mechanical treatment, averaging $155 per acre.

About 2 million acres were planted in the South in 1997 (Moulton 1999). The acreage was nearly evenly split between nonindustrial private forest (NIPF) landowners and forest industry. Direct seeding accounted for only 0.4 percent of the total. Nearly 1.3 billion seedlings were produced in southern nurseries, and the average planting density was 618 trees per acre. The "Cost Trend Survey" found that most planting (79 percent) was done by hand rather than by machine. Machine planting is slightly more expensive, averaging $45 per acre compared to $39 per acre for manual work. Machine planting is also more constrained by site conditions, such as debris, slope, and soil moisture. Seedling costs vary considerably, depending on species, genetics, and product form. One source, for example, lists containerized loblolly pine seedlings for $155 per thousand, while similar seedlings in bare-root form are $46 per thousand. Thus, total costs for planting may range from $85 to $200 per acre.

With these significant investments in site preparation, improved seedlings, and planting, fertilization is increasingly common in the South. Almost 1.6 million acres were treated in 1999 (North Carolina State Forest Nutrition Cooperative 1999). Some applications are at stand establishment to promote initial growth, but about two-thirds of the treated acres are in established stands (Jokela and Stearns-Smith 1993). The most common fertilizers are dry solid forms of urea (for nitrogen) or diammonium phosphate (for nitrogen and phosphorus). The "Cost Trends Survey" found that nearly all fertilizer is applied by airplane or helicopter.

Technology for stand management and product recovery—Many prescriptions call for manipulation of vegetation in established stands: thinning, sanitation removals of diseased or infested trees, regeneration cuttings in shelterwood or group-selection systems, and harvest of crop trees. All of these treatments involve some type of felling and, in most cases, processing and extraction. Stokes and Watson (1996) describe a range of systems for plantation thinning, and Stokes (1991) outlines systems used in southern timber harvests. These systems are sometimes defined by the forest product that is produced (pulpwood or sawlog). These distinctions, however, are less definitive today as multiproduct harvesting becomes more common. A more useful description may be the level of mechanization, from animal logging systems to helicopters.

Animal logging was replaced by tractor logging in the 1930s to reduce costs. Yet, 60 years later, animal logging systems are still found in the southern forest as specialty operations. Various surveys indicate a public perception that animal logging is ecologically and visually preferred over more mechanized systems. Toms (1999) described current animal logging systems used in Alabama. In all of these operations, felling, delimbing, and processing are done with chainsaw. Trees are bucked at the stump to log lengths for primary extraction with animals. Most crews take two animals to the woods and work them as singles rather than as a team. Systems vary in extraction and loading. The traditional animal logging crew skids logs to a loading point where a self-loading truck (a side-loader or a big-stick loader) can access the material. Some crews use a front-end loader or knuckleboom to increase productivity. A final variant is a hybrid system that combines animal prebunching with subsequent extraction by a conventional skidder or forwarder.

Production is relatively low with animal logging systems. Toms (1999) found average weekly production ranged from 2,500 cubic feet for the traditional system to 7,000 cubic feet for the hybrid variant. Terrain, skidding distance, crew experience, and degree of mechanization are critical factors affecting the production rate. Uphill skidding or heavy brush can significantly reduce output. To maximize productivity, animal loggers prefer to work in large timber where one-log loads approach full capacity and at short extraction distances. A study in the Missouri Ozarks (Ficklin and others 1997) observed mules operating at skidding distances of 1,050 feet, but Toms and others (1996) found an average skidding distance of less than 200 feet.

The low production rate and minimal move-in costs make animal logging operations most competitive on small harvest units. As long as total harvest volume exceeds several loads, there is little economic penalty associated with small tracts. In fact, the smallest unit reported by Toms (1999) was a 1-acre tract, and the median tract size was only 20 acres.

The primary advantages of animal logging are minimal soil disturbance and residual tree damage, suitability to small tracts and selective cutting, and minimal noise and pollution. Balancing these advantages, however, are the low overall production rate, a significant reduction in productivity with small diameter pieces, stand disturbance associated with loading and woods roads, and the need to minimize skidding distance.

In 1998, an extensive survey of animal logging in Alabama identified 52 contractors mostly operating in the northern half of the State (Toms and others 1998). Assuming an average production of 4,000 cubic feet per week, the total output of animal loggers in Alabama represents less than 0.5 percent of the statewide roundwood harvest in 1995 (Johnson and others 1998).

Mechanizing the extraction function of an animal logging system leads to the manual cable skidder system. In this operation, trees are manually felled, limbed, and topped. A rubber-tired cable skidder pulls logs to a landing for loading. The unique feature of cable skidders is their ability to winch logs. By pulling cable from the skidder to the log, trees may be pulled into a skid trail with little soil disturbance. The winch is also useful on wet sites when the skidder loses traction. By slacking the winch and driving ahead, the load can be pulled through the trouble spot. Cable skidder systems are typically used in broken, steep, or wet terrain, in large-diameter sawtimber, and in selection harvests.

The feller-buncher and grapple-skidder system has significantly increased harvesting productivity. Feller bunchers fell trees with either a saw or shear and then place the trees in bunches for further handling. By accumulating felled trees in piles, the feller buncher makes the subsequent skidding process more productive. Grapple skidders take advantage of the bunched wood by grasping a full load with a large pincer on the back of the machine. Cable skidder operators, in contrast, have to stop and tie a wire rope to each tree. With most feller-buncher systems, the wood is skidded in tree lengths to either a landing or a processing area for delimbing. Gate delimbers are large steel grates that are set in the woods at some distance from the landing. By backing the load of trees through the grate with the skidder, most pine limbs can be broken off. A landing sawyer may be employed to clean up the wood prior to loading. Stroke delimbers, loader-mounted, pull-through delimbers, and flail delimbers (Mooney and others 2000) are gaining acceptance to improve delimbing quality, reduce waste, and eliminate manual chainsaw work. A typical feller-buncher and grapple-skidder system includes one feller buncher, two grapple skidders, a gate delimber, and a knuckleboom log loader. If products are sorted out, higher value products are bucked from the tree-length pieces at the landing either by chainsaw or slasher. These systems find greatest application in even-aged stands with trees of uniform size and high pulpwood volumes.

In-woods chipping is an extension of the feller-buncher and grapple-skidder system. In these operations, a flail-chipper is added at the landing to produce pulp-quality chips from tree-length stems. A spinning chain flail removes bark and limbs, and the clean stem is chipped and blown into a waiting van. Watson and others (1991) found that in-woods chipping produced chips of comparable quality to mill-produced chips. Flail chipping actually left a higher percentage of total tree biomass in the stand (31 percent) compared to conventional tree-length harvesting (24 percent). The system is balanced to the productivity of the chipper. Thus, a typical in-woods chipping operation may require two feller bunchers, three skidders, a loader, and the chipper. High production is necessary to support the cost of the equipment. Munn and others (1998) noted an average production of about 500 tons per day for in-woods chipping. A similar system without the flail debarker may be used to produce fuel chips.

Cut-to-length (CTL) technology produces a different product form at roadside. It is a ground-based system in which felled trees are processed at the stump into defined log lengths. Characteristically, the CTL wood is transported to roadside on a forwarder, a machine that carries rather than drags wood. Forwarders were used years ago in southern shortwood operations. CTL technology has been advanced in Scandinavia, where it is the state-of-the-art system for forest harvesting. Modern harvesters fell trees and process them through computerized harvester heads that delimb and buck trees to optimum product lengths. Eight-wheeled forwarders accumulate, sort, transport, and load wood onto highway trailers. A key advantage of CTL systems is that they process trees in the woods, leaving a layer of limbs and tops on the ground to drive over. This reduces soil disturbance and compaction. Lanford and Stokes (1996) compared a CTL system with a feller-buncher and grapple-skidder system in a pine thinning and found that costs and productivity of the two systems were practically equivalent.

Several specialized systems have been developed for wet sites (Stokes and Rummer 1997). Operations typically incorporate modifications to improve driving on soft soils. Conventional feller bunchers may be adapted by using a wide-tracked feller buncher. Skidders can be equipped with either wide tires or dual tires to reduce ground pressure. Tires up to 72 inches wide may be used. Large-capacity extraction machines have also been developed to reduce the need for roads on wet sites. Clambunk skidders may drag up to three times the load of regular skidders. Tree-length forwarders carry a full truckload of wood supported on 10 wide tires. Both clambunks and tree-length forwarders can be combined with tracked feller bunchers and skidders for felling and short-distance extraction.

Shovel logging is another adaptation for wet sites. Originally developed in the Pacific Northwest, shovel logging was modified in the 1990s for southern conditions. The basic system uses a tracked feller buncher to fell and pile trees. A second tracked machine, the shovel logger, moves felled trees and aligns them into a solid mat of wood to form a skidtrail. When the skidtrail is complete, dual-tired grapple skidders start at the farthest end of the road, picking up the mat of wood as they go. By traveling on the constructed skidtrail, shovel logging reduces rutting and soil disturbance.

Cable logging is another specialized method of extracting material on adverse sites, particularly on slopes greater than 35 percent. In cable logging, a long wire rope is suspended across the stand. A winch (the yarder) sits at the landing and pulls logs along the suspended cable. Depending on terrain and equipment, a cable system may simply drag logs from the stump, or it may completely lift them off the ground. Units can be relatively large, with extraction distances of one-quarter mile. With long extraction distance, it is critical to fully load the system on each turn. Thus, cable logging requires special skills among sawyers and choker setters. Product forms are limited by the possible load sizes for the cable. Planning is critical to meeting production and cost goals. However, LeDoux and others (1995) estimate that cable systems make 14 percent of the upland hardwood forest in the Southern United States economically operable.

Helicopters also can extract forest products where access is limited by soft soils or steep terrain. Helicopters are expensive to operate, so high hourly productivity is needed to achieve economic viability. Material to be removed is felled and bucked before the arrival of the helicopter and extraction crew. During extraction, teams of choker setters preset lines on the felled material in optimum load-sized bundles. The helicopter pauses in the woods just long enough for the choker setters to connect the drop line to a bundle. After a short flight to the landing zone, the helicopter releases the load and returns to the woods. Sirois and Stokes (1986) and Jackson and Morris (1986) observed a helicopter crew operating in cypress swamps in coastal South Carolina. The operation required a crew of 14, plus a front-end loader and a knuckleboom loader. At extraction distances of 900 to 2,900 feet, cycle times ranged from 1.74 to 5.35 minutes. Average production was about 3,100 cubic feet per scheduled hour of operation. Willingham (1989) described the initial configurations of helicopter logging with Scott Paper Company in the Mobile Delta. Their system consisted of manual felling followed by helicopter extraction to a riverbank, where logs were loaded on a barge. The system evolved to include tracked feller bunchers and a purpose-built helicopter to maximize efficiency.

Another application of helicopters is in steep terrain, where roadbuilding costs are high and ground-based extraction is difficult. Sloan and others (1994) reported on the use of a K-MAX logging helicopter for a shelterwood harvest in the mountains of Virginia. Working at an average extraction distance of 1,900 feet, the operation was estimated to produce 1,300 cubic feet per hour.

Helicopters are not limited by ground conditions; but they are limited by weather, altitude, and piece size. In order to accumulate full loads, helicopter logging requires a particular minimum volume per acre. Hourly costs are very high. The reported operating costs in 1986 were about $2,000 per hour, including support but not felling. To avoid delays, the landing zone must be large enough to safely handle the loading of 15 to 20 trucks per day. The primary advantages of helicopter logging are the reduction of soil disturbance associated with roads and skidtrails and the reduction in roadbuilding costs. With the fast cycle times, helicopters are also able to operate economically at longer extraction distances than most ground-based systems.

Operations training—A key component in forest operations technology is the skill and expertise of loggers. For decades, loggers have had opportunities for continuing education through workshops and seminars covering a range of topics. In the late 1980s, the Logger Education to Advance Professionalism (LEAP) program was initiated in the Northeastern United States to improve loggers' understanding of basic silviculture and resource management. Participation in continuing education was voluntary until the mid-1990s. When Occupational Safety and Health Administration (OSHA) released new logging safety regulations in 1996, it created a regulatory requirement for logging safety training. The OSHA rules closely followed the development of the Sustainable Forestry InitiativeK in 1995 by the American Forest & Paper Association. Member companies support education programs through financial contributions and by performance expectations established for their suppliers. In response, all but one Southern State developed some form of logger training and education (Forest Resource Association 2000). Oklahoma sends its people to courses in Arkansas. Curricula vary, but generally include safety and first aid, business management, best management practices (BMPs), environmental considerations, and forest management. Some courses are for supervisors, while others are for workers. Graduates receive formal recognition and may be required to remain current through continuing education. In 1999, 8,254 contractors and employees completed some form of a logger training and education course.

Operations prevalence and productivity—The 1990 Census (U.S. Census Bureau 2000b) reports 51,525 workers engaged in logging (Occupational Codes 494 and 496). Figure 15.1 shows the distribution of these logging workers across the South. Note that significant numbers of timber cutters are in counties with no forest

TIMBER

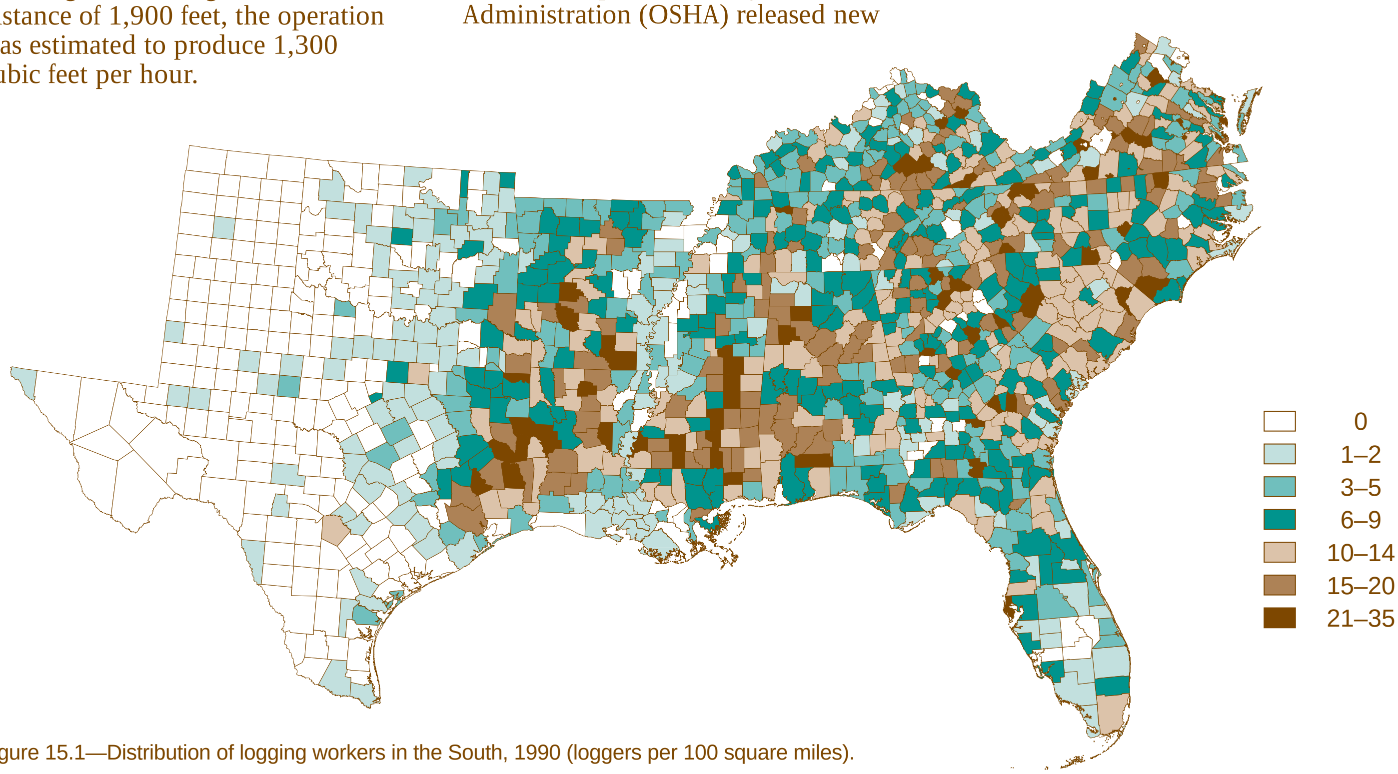

Figure 15.1—Distribution of logging workers in the South, 1990 (loggers per 100 square miles).

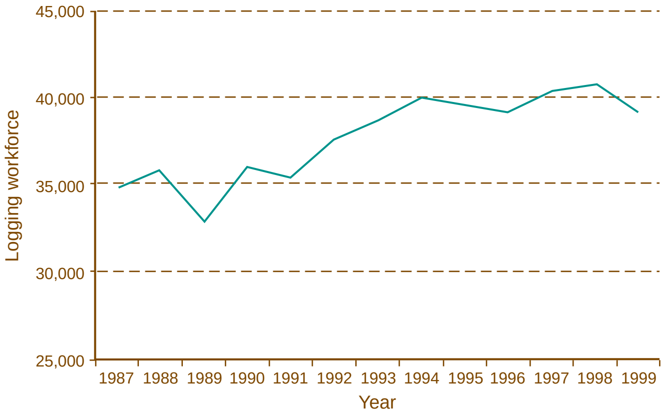

Figure 15.2—Changes in the logging workforce in the South, 1987 to 1999.

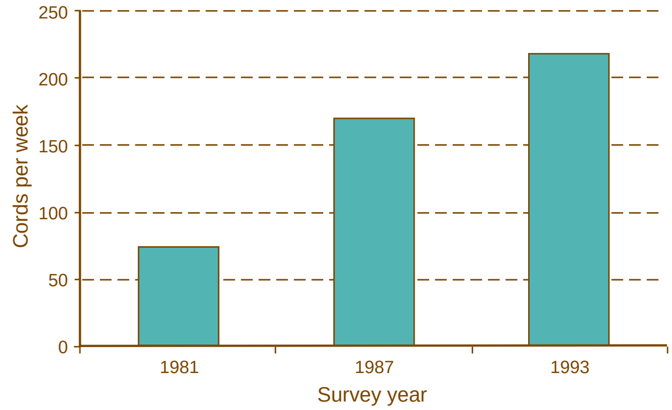

Figure 15.3—Average weekly crew production from pulpwood producer surveys, 1981 to 1993.

products output. This is particularly apparent in Texas, Oklahoma, and Florida, where there are concentrations of workers in metropolitan areas. These likely represent urban treecutters who clear land and perform arborist services. It is probable that other metropolitan areas have similar numbers of nonforest timber cutters. The ES-202 Covered Employment data suggest a 1999 southern logging workforce of 43,234, approximately a 15-percent increase over the last decade (fig. 15.2).

A number of studies document characteristics of these southern loggers. The Southern Technical Divisions of the American Pulpwood Association conducted a series of pulpwood producer surveys periodically from 1976 to 1993. The most recent report from the 1993 data (Munn and others 1998) located 8,700 contractors with 46,580 employees, operating in 11 Southern States (not including Kentucky or Oklahoma). Based on workforce estimates and pulpwood production reported, the survey sample was a nearly complete census of pulpwood producers. The most common harvesting configuration was a rubber-tired feller buncher working with grapple skidders to extract wood for tree-length transport. Most delimbing and topping were done with chainsaws, but delimbing gates were used in about half of the operations. Less than 3 percent of crews used in-woods chippers. From the receiving mills' perspective, about 78 percent of the wood volume was produced by only 28 percent of the crews. Almost half of the pulpwood logging crews sampled produced less than 70 tons per week. The periodic sampling of pulpwood producers shows a clear increase in crew productivity over the last 20 years (fig. 15.3).

In their analysis of successful logging contractors, Stuart and Grace (1999) reported that productivity increased by about 12 percent between 1994 and 1997. In the sample of the upper quartile of loggers, productivity averaged about 60,000 tons per year. Greene and others (2001) found that weekly production of Georgia loggers nearly doubled from 1987 to 1997. Capital investment per cord remained nearly constant over the decade, while labor productivity increased by 79 percent.

Combining the logging population data with TPO production figures provides an overview of logging productivity variations across the South (fig. 15.4). Productivity was negatively related to percent hardwood production. Productivity was highest on the Coastal Plains and decreased through the Piedmont to the Appalachians and Interior Highlands.

The various assessments of the logging workforce show a diverse range of forest operations in the southern forest. The majority of fiber is produced with high-production, ground-based systems. However, the majority of forest operators are small contractors with relatively low productivity. Technology has been developed to meet most conceivable forest conditions in the South. However economic viability limits the options of loggers and landowners.

Technology Impacts on Productivity and Management Choices

Rational selection of a management regime (rotation length, timing and type of intermediate treatments, etc.) should be based on landowner objectives, scientific management principles, and economic analysis. For any management prescription, there may be a range of alternative technologies that vary in objective attainment and cost. The manager must select a system that provides the greatest benefits at the least cost.

An economic analysis to determine the optimal rotation age will include the costs and timing of all management activities and the estimated returns. In the traditional (Faustmann) economic model, increasing harvesting costs extend the economically optimum rotation age. Prestemon and others (2000) analyzed data from the Southern Appalachians of North Carolina and Virginia to determine whether forest management decisions were consistent with economic viability. Results indicated that stand age increases with distance to markets, increasing slope, and decreasing site class. These findings would be expected under the traditional economic model and were observed across all ownership types (NIPF, industry, and government). Similarly, Brown (1990) analyzed harvesting activity on both wet and steep sites in the South. About 10 percent of southern forest sites were classified as adverse, mostly due to slopes over 40 percent. Harvesting rates on difficult sites were one-fifth of those on easily accessible sites. As a result, stands on difficult sites are older and have higher timber volumes. Barlow and others (1998) also found decreasing harvest rates with increasing slope and distance to roads; both factors increase harvesting costs.

While high harvesting costs increase rotation length, high site-preparation and establishment costs tend to reduce rotation length. The objective of intensive regeneration practices is to increase survival and growth, leading to economic maturity at an earlier age. The economic consequence is a shorter rotation to recover these costs earlier.

Haight (1993) added consideration of variation in future product prices to the traditional economic model. He based the timing of the final harvest on a comparison of current prices with a calculated reservation price. When prices exceed the reservation price, harvest is indicated. Plantinga (1998) notes that the reservation price model generally leads to longer rotations than the fixed rotation age calculation. Haight modeled a range of site preparation alternatives and found that the moderate treatment (chopping, burning, plant) had a higher expected present value than either an intensive or a natural regeneration option. In addition, this analysis found nearly a 20-percent increase in return due to timing the final harvest based on price expectations.

While an economic analysis may affect the selection of rotation length, in some cases the total costs may render any forest management uneconomical. May and LeDoux (1992) analyzed FIA plot data for Tennessee and estimated harvesting and stumpage prices for timberland. At medium stumpage prices, 51 percent of timberland was estimated to be profitable to harvest. At low stumpage prices, only 72 percent of the total timberland acreage could be economically managed. A similar approach was used in western Virginia (Worthington and others 1996). Under current market conditions, about one-third of the timberland in the study area would be unprofitable to manage.

Technology is being sought to reduce costs of forest operations. Such savings, however, cannot alter land management practices unless they are passed on to the landowner in the form of stumpage price increases. Most cost-saving technology now is being directed to controlling rising operational costs. Stuart and Grace (1999) noted that average logging costs per ton increased 16 percent between 1994 and 1997. During the same period, the Producer Price Index (PPI) for contract logging services only increased 4 percent (U.S. Department of Labor, Bureau of Labor Statistics 2000b). For the entire decade 1990 to 2000, the PPI for contract logging increased only 9 percent. Clearly, there is significant cost pressure on logging contractors. Costs of some site preparation treatments are also rising faster than inflation. Costs of prescribed fire nearly doubled in the last decade (Dubois and others 2001). Precommercial thinning and mechanical site preparation costs increased 30 percent. Costs for chemical treatments were up 20 percent, and those for hand planting rose 25 percent. Labor costs have increased with rising workers' compensation rates. With these price pressures, much of the technology to reduce costs is focused on maintaining profitability of logging contractors or for controlling wood costs at the receiving mill. Larger skidders and better delimbers are examples of developments to reduce costs through elimination of labor. It is unlikely that these cost savings will be passed back to landowners. The increase in mechanization as an approach to controlling logging costs has also resulted in more highly capitalized systems that derive efficiency from high volume production.

Impacts of Forest Operations

Forest operations alter the environment. Some of these effects are intended; others are undesirable consequences. Most impacts are associated with driving equipment and moving material in the forest. Soil, water, and residual vegetation can be affected. Effects must be considered in terms of their quantity, severity, persistence and location within the

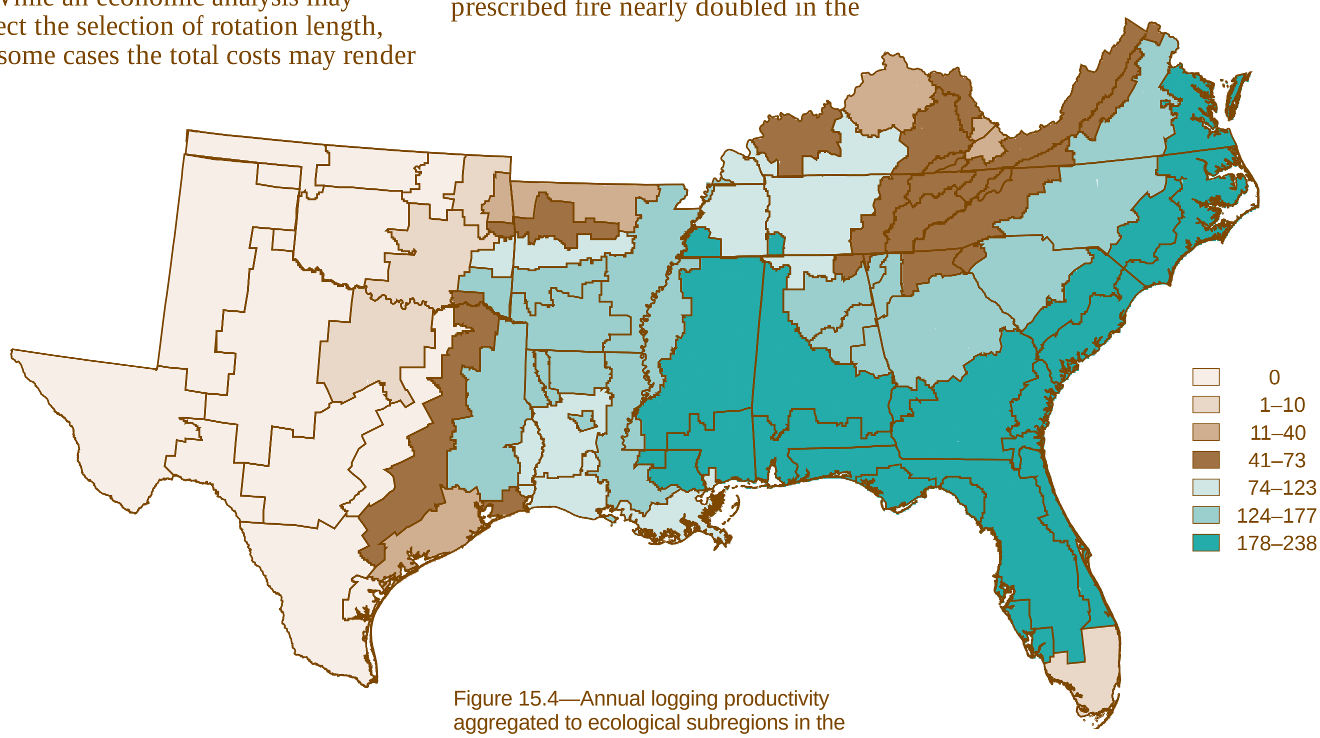

Figure 15.4—Annual logging productivity aggregated to ecological subregions in the South (thousand cubic feet per logger).

landscape. Some impacts are short-lived, while others may affect the long-term productivity of the forest. Impacts that are concentrated may be significant, while the same impacts spread across a stand may not be ecologically important. Chapters 21, 22, and 18 provide more information about the effects of forest management on water and soil.

The principal impact of most forest operations is soil disturbance. Soil disturbance results from road or trail construction, equipment traffic, and the dragging of material. Soil disturbance includes physical dislocation and loosening, compaction, or puddling. Disturbance effects are the cumulative result of all operations in a silvicultural system. Soil disturbance from felling is covered by soil disturbance from skidding, which is subsequently ameliorated by the soil disturbance associated with site preparation.

Conventional clearcut skidder harvesting systems cover about 15 percent of the stand in trails and landings. The most heavily impacted areas are the primary skid trails, gate delimbing areas, and landings. Detailed tracking of total soil disturbance on a Piedmont clearcut showed about 22 percent of the stand affected by more than five passes of machinery (McDonald and others 1998). At least 30 percent of the stand remains undisturbed, even in clearcuts. Reisinger and others (1988) summarized studies from the South and noted that 63 to 99 percent of the stand areas were undisturbed, depending on the system used.

More difficult sites tend to have a greater amount of undisturbed area than more easily accessible areas. Stuart and Carr (1991) and Stokes and others (1998) observed that disturbed area decreased with increasing slope. On slopes greater than 35 percent in central Virginia, skidtrail disturbance ranged from 3 to 10 percent of the stand. In contrast, Aust and others (1993) found 34 percent of a wet flat rutted.

Harvest intensity also affects the amount of soil disturbance. Kluender and others (1994) and Carter and others (1997) found that clearcuts and shelterwood cuts had similar amounts of skidtrail disturbance (about 15 percent of the stand). Shelterwoods, however, had more area in undisturbed condition. Single-tree selection had the least amount of soil disturbance, but that prescription calls for more frequent entries with additional impacts over time.

CTL systems carry wood rather than dragging it over the soil. The result is less soil disturbance. Vidrine and others (1999) and Lanford and Stokes (1995) found that seventh and fifth row thinning in pine plantations with a harvester/forwarder combination resulted in 11 to 30 percent of the total stand area disturbed by traffic. Both of these studies were on Coastal Plain sites in winter. Seixas and others (1995) compared five CTL configurations in various prescriptions and found the least disturbance occurred with a feller buncher, manual processing, forwarder system. About 26 percent of the stand area was disturbed. A system with a drive-to-tree harvester and forwarder disturbed 39 percent, and a horse logging crew disturbed 42 percent of the stands.

Cable logging reduces soil disturbance because wheeled traffic is eliminated in the stand. Disturbance still occurs from dragging logs, however, Miller and Sirois (1986) compared skidder and cable logging in southwestern Mississippi. About 16 percent of the cable units were disturbed, mostly in cable corridors. Skidders disturbed about twice as much area. Cable logging disturbance tended to be oriented up-and-down slope, while skidder disturbance was more irregular.

Forestry tires have gotten larger to provide better flotation and reduce rutting and disturbance. Wider tires typically reduce rut depth but increase track width (McDonald and others 1995). Thus, the primary application of wide tires appears to be on very soft soils where sinking and rutting are concerns. Carruth and Brown (1996), for example, noted that when moisture content exceeds 40 percent on lower Coastal Plain sites, the only systems that can operate are tracked feller bunchers and wide-tired skidders operating on trees and mats. On drier soils in eastern North Carolina, Seixas and McDonald (1997) observed that the least rutting developed with narrower tires on a forwarder rather than wider tires or tires with tracks. Rummer and Sirois (1984) observed that carrying larger loads on wider tires probably offset any reduction in soil loading.

Operational configurations that carry, rather than drag, materials generally produce less soil disturbance. Feller bunchers generate less disturbance than manual felling because trees are carried from the stump to the bunching location. Forwarders generate less disturbance during extraction than skidders because the load is off the ground. Swing machines have arms and rotating upper structures; they cause less disturbance than drive-to-tree designs. Swing machines can often reach into the stand to perform work without driving over every area.

Operating methods can also reduce soil disturbance. Designating skid trails can manage and minimize the amount of area impacted. Shovel logging is a method of logging that limits heavy traffic to a road of felled trees. When the trees are picked up, the underlying soil is minimally affected. Similarly, CTL operations can process trees in front of the machines, building a trail mat of limbs and tops. Seixas and others (1995) found that soil compaction was reduced under the heavier layers of the slash mat.

Cumulative soil disturbance can also be reduced by follow-up treatments to ameliorate adverse effects. BMPs typically call for vegetative stabilization of exposed soil that may be a sedimentation risk. Compacted areas may be subsoiled, ripped, or disked during site preparation to improve physical properties. On well-drained sites, survival and growth of loblolly pine have been positively affected by subsoiling treatments. On wet sites, bedding can create drier planting sites where harvesting has resulted in raised water tables (Aust and others 1998).

Accessibility to Various Ownership Groups

Forest operations accessibility depends primarily on economic viability. Economic viability, in turn, depends on whether the perceived value of the treatment exceeds the costs of implementation. A thinning, for example, may not have a short-run positive cash flow, but the increased value of the residual stand is expected to yield a profit over the rotation. Similarly, a landowner may realize no tangible return from creating a wildlife opening, but the intangible benefit of viewing wildlife may be deemed greater than the incurred costs. A prescription to achieve a given management objective establishes a set of operating conditions, such as extraction distance, volume per acre handled, seasonal restrictions, and slope, which will determine the operating costs for a particular forest operations technology. The prescription also determines the time frame over which expenses must be amortized and the values of the anticipated outcomes.

In the context of differences among various ownership groups, economic viability of forest management is primarily affected by the selection of management regimes and variations in tract size. Thompson and Johnson (1996) profiled NIPF landowners in Virginia and identified three subgroups: (1) farmer-owned, (2) other corporate, and (3) other private individual. Bliss and others (1997) surveyed NIPF owners in the Tennessee Valley and examined differences among income, ownership size, and management activity. Differences in accessibility of forest operations technology to any of these forest ownership groups depends on whether they fundamentally differ in their management objectives or in the size and composition of their forest holdings. See chapter 9 for additional information on the management objectives of various ownership groups.

Tract size may be the most important factor affecting economic viability of management activities. Row (1978) notes that the diseconomies of small tract size may reduce the willingness of landowners to invest in forest management. In the Virginia survey (Thompson and Johnson 1996), about 11 percent of the NIPF holdings were in tracts less than 10 acres; and 40 percent were in tracts less than 50 acres. The smallest average tract size was in the natural pine management type.

Generally, an economy of scale is realized by spreading fixed costs of ownership and management over more units of output (Cubbage 1983). In forest management, many costs must be recovered through value generation at some point in the management regime. For example, fire protection, boundary maintenance, and administration and planning are costs that vary little with tract size. In harvesting, costs for moving and planning accrue without respect to tract size. Greene and others (1997) analyzed the effect of tract size on harvesting costs. Their assumptions were based on a survey of recent timber sale volumes and tract sizes in Georgia. Figure 15.5 illustrates estimated production costs for three alternative systems using cost equations derived from the simulation analysis. Note that above 20 acres, all of the systems have relatively flat cost curves. Conversely, below 10 acres all of the systems demonstrate significantly increasing costs.

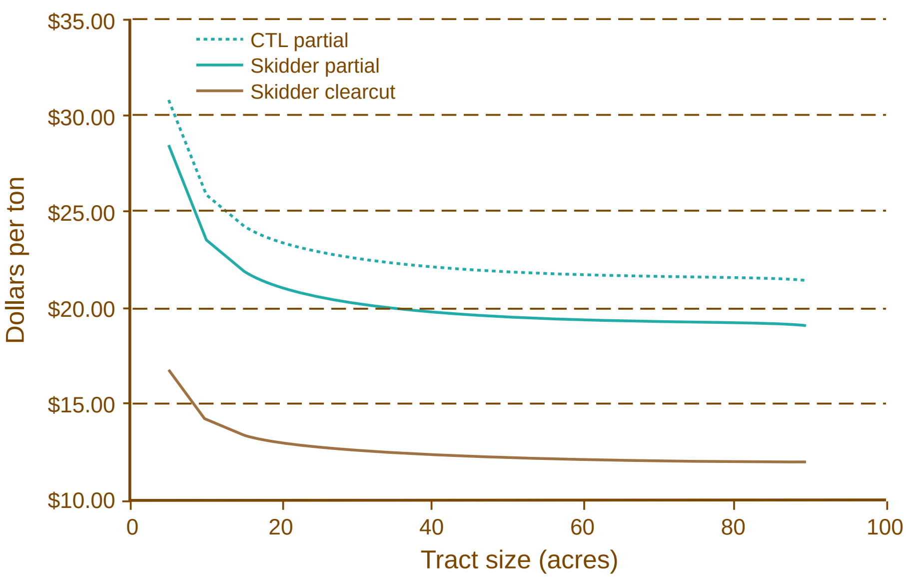

Figure 15.5—Predicted costs of harvesting 40 tons per acre in trees averaging 9 inches diameter at breast height.

Many studies have examined the effect of removal intensity on harvesting costs (Brummel 1993, Kluender and others 1998, Rummer 1998). Generally, there is little reduction in system productivity for prescriptions that leave a moderate residual stand, such as a seed-tree or shelterwood. However, when harvesting in small blocks, as with group selection or single-tree selection, productivity declines and costs increase. In selection harvests, other factors, such as the effect of selection criteria on average tree size, may be more important than tract size in determining economic operability.

Discussion and Conclusions

Forest operations technology is changing in the South. Tree-length logging and hauling have largely replaced shortwood operations. Labor-intensive bobtail crews, once the mainstay of pulpwood logging, are becoming harder to find.

The primary driver of change is economic viability. Labor costs have gone up, and the pool of able employees has been shrinking. The result has been a shift towards more mechanized operations with higher productivity per person. Site preparation and establishment costs have increased sharply. While new technology, such as fertilization, can increase yields, its costs must be closely examined to make sure the net financial return is positive. Rosenberg and others (1990) discuss the development and adoption of new technology in the forest products industry. They note that the adoption of new panel products in the 1970s and 1980s was not due to breakthrough technology (the basic technology had been developed 20 years previously), but rather to significant shifts in the price of veneer logs, which were the raw materials for conventional plywood. Relatively suddenly, the economic environment had changed.

A secondary driver of change has been the development of ecological issues. Water-quality concerns led to the development and promulgation of BMPs and logger training initiatives. Aesthetic values have become better defined and guidelines for minimizing visual impacts have been developed.

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Our growing understanding of nutrient cycling and global carbon sequestration is leading to new technologies and opportunities in southern forests.

Neither economics nor ecology are optional. Southern forest management is not feasible if it cannot offer positive economic returns. Similarly, forest management is not tenable if it cannot maintain or enhance ecological functions. New technology must be constantly pursued to meet these continuing challenges. Yet Rosenberg and others (1990) observe that new technology is seldom the perfect solution to a problem. Innovations often have undesirable as well as desirable traits. The adoption process proceeds over time to reduce the adverse effects while optimizing the benefits. CTL is probably an example of this process. Modern CTL systems were developed and optimized in Scandinavia with very different labor, product, and cost structures. While CTL has some very good attributes, there are significant reservations about widespread adoption in the South at this time.

Another barrier to the adoption of new technology is the integration of forest operations. All parts of an operations system must be compatible with one another. Wood is hauled tree-length because the mills are set up to receive that form. Heavy traffic from ground-based systems defines the need for subsoiling. Changes in technology have to fit the existing framework of silviculture, products, processes, and culture.

Developments in information technology will be a central factor in all future management. Geographic Information Systems (GIS) permit the presentation, manipulation, and transfer and storage of map-type data. Increasingly, resource managers utilize GIS to develop and design prescriptions that better address the variation of conditions across the landscape. Geographic Positioning Systems (GPS) will allow operations technology to implement more complex treatment plans that are better adapted to site-specific ecological features.

Variation in the southern forest is a key factor that works both for and against innovation and new technology. Given the wide range of operating conditions from Virginia to Texas, it is unlikely that many new forest operations will find widespread application. New technology has to find its niche, and that niche must be large enough to warrant the necessary development costs. The variety of forest conditions, however, also supports innovation. Shovel logging, for example, was a niche system designed for upland sites in the Northwest. That concept, however, sparked new thinking about how to work in wet sites of the South.

Technology is developed in response to needs. Forest management defines a need, and technology delivers a solution. Forest industry defines a need for fiber in a specific form, and logging systems are modified to provide that form. The process of technological progress can be slow. Yet progress—both economic and ecologic—is evident in southern forest management. Even more new technology is waiting in the wings for the right need, the right place, and the right time.

Needs for Additional Research

Little specific information is available on the distribution and characteristics of niche technologies. Shovel logging systems, animal logging, CTL, and modern cable skidding are not well documented in the South. Land managers and contractors have little quantitative basis for the selection of appropriate technology on some tracts. This information will become more important as more site-specific prescriptions evolve. If timber markets expand, niche systems will also be sought for application on adverse sites, such as wet or steep terrain.

There is also a critical need for technology to manage smaller tracts, smaller diameters, and lower volumes per acre. Chapter 6 describes trends in ownership patterns, tract size, and fragmentation. It is an open question whether there are realistic silvicultural prescriptions for many small NIPF holdings, but the lack of mechanized operations that can operate economically where volumes are small affects many forest owners in the South.

The conventional ground-based operations that are used to produce the majority of timber in the South will continue to be refined by producers and equipment manufacturers through product development. However, research into the effects of planning and work organization may be able to generate cost savings and reduce adverse impacts.

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Tom Bailey, Soil Scientist, USDA Forest Service, provided background information and reviewed the literature on operations impacts. Mark Dubois assisted with the presentation of "Cost Trend Survey" data.

Literature Cited

Anon. 2000. Forest inventory and analysis timber product output (TPO) database retrieval system. http://www.srsfia.usfs.msstate.edu/rpa/tpo. [Date accessed: December 21].

Aust, W.M.; Reisinger, T.W.; Burger, J.A.; Stokes, B.J. 1993. Soil physical and hydrological changes associated with logging a wet pine flat with wide-tired skidders. Southern Journal of Applied Forestry. 17(1): 22–25.

Aust, W. Michael; Burger, James A.; McKee, William H. [and others]. 1998. Bedding and fertilization ameliorate effects of designated wet-weather skid trails after four years for loblolly pine plantations. Southern Journal of Applied Forestry. 22(4): 222–226.

Barlow, Stephen A.; Munn, Ian A.; Cleaves, David A.; Evans, David L. 1998. The effect of urban sprawl on timber harvesting. Journal of Forestry. 12(1): 10–14.

Bliss, John C.; Nepal, Sunil K.; Brooks, Robert T.; Larsen, Max D. 1997. In the mainstream: environmental attitudes of mid-South forest owners. Southern Journal of Applied Forestry. 21(1): 37–43.

Brown, Mark J. 1990. Harvest rates on adverse sites in the Southeast. Southern Journal of Applied Forestry. 14(4): 166–170.

Brummel, Kenneth R. 1993. Timber harvesting costs and group selection silviculture. Tech. Release 93–R–42. Rockville, MD: American Pulpwood Association. 2 p.

Busby, Rodney L.; Miller, James H.; Edwards, M. Boyd. 1998. Economics of site preparation and release treatments using herbicides in central Georgia. Southern Journal of Applied Forestry. 22(3): 56–162.

Carruth, J. Steven; Brown, James C. 1996. Predicting the operability of South Carolina Coastal Plain soils for alternative harvesting systems. In: Planning and implementing forest operations to achieve sustainable forests: Proceedings of the joint meeting of the Council on Forest Engineering and International Union of Forest Research Organizations. Gen. Tech. Rep. NC–186. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 47–53.

Carter, Emily; Rummer, Bob; Stokes, Bryce. 1997. Site disturbances associated with alternative prescriptions in an upland hardwood forest of northern Alabama. Pap. 97–5013. St. Joseph, MI: American Society of Agricultural Engineers. 18 p.

Cubbage, Fred. 1983. Economics of forest tract size: theory and literature. Gen. Tech. Rep. SO–41. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 21 p.

Dubois, Mark R.; Erwin, Chris; Straka, Thomas J. 2001. Costs and cost trends for forestry practices in the South. Forest Landowner. 58(2): 3–8.

Ficklin, Robert L.; Dwyer, John P.; Cutter, Bruce E.; Draper, Tom. 1997. Residual tree damage during selection cuts using two skidding systems in the Missouri Ozarks. In: Proceedings of the 11th central hardwood forest conference. Gen. Tech. Rep. NC–188. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 36–46.

Forest Resource Association. 2000. Sixth report on the status of statewide logger training and education programs in thirty-two forested States. Rep. 00–A–2. Rockville, MD: Forest Resources Association. 76 p.

Greene, W. Dale; Harris, Thomas G.; DeForest, Christopher E.; Wang, Jingxin. 1997. Harvesting cost implications of changes in the size of timber sales in Georgia. Southern Journal of Applied Forestry. 21(4): 193–198.

Greene, W. Dale; Jackson, Ben D.; Culpepper, Jack D. 2001. Georgia's logging businesses, 1987 to 1997. Forest Products Journal. 51(1): 25–28.

Groninger, John W.; Stein, Henry D.; Zedaker, Shepard M.; Smith, David W. 1998. Growth response and cost comparisons for precommercial thinning methods of Appalachian oak stump sprout clumps. Southern Journal of Applied Forestry. 22(1): 19–23.

Haight, Robert G. 1993. Technology change and the economics of silvicultural investment. Gen. Tech. Rep. RM–232. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 18 p.

ISO. 1999. Machinery for forestry—mobile and self-propelled machinery—terms, definitions, and classification. ISO/FDIS 6814. Geneva: International Organization for Standardization. 11 p.

Jackson, Ben D.; Morris, Robert A. 1986. Helicopter logging of bald cypress in southern swamps. Southern Journal of Applied Forestry. 10(5): 92–95.

Johnson, Tony G.; Gober, Jim R.; Nix, J. Stephen. 1998. Alabama's timber industry—an assessment of timber product output and use, 1995. Resour. Bull. SRS–27. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 28 p.

Jokela, Eric J.; Stearns-Smith, Stephen C. 1993. Fertilization of established southern pine stands: effects of single and split nitrogen treatments. Southern Journal of Applied Forestry. 17(3): 135–138.

Kluender, R.; Lortz, D.; McCoy, W. [and others]. 1998. Removal intensity and tree size effects on harvesting cost and profitability. Forest Products Journal. 48(1): 54–59.

Kluender, Richard A.; Lortz, David A.; Stokes, Bryce J. 1994. Production time, total costs, and residual damage at varying harvest intensities. In: Proceedings of a symposium on ecosystem management research in the Ouachita Mountains; pretreatment conditions and preliminary findings. Gen. Tech. Rep. SO-112. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 229–240.

Lanford, Bobby L.; Stokes, Bryce J. 1995. Comparison of two thinning systems. Part 1. Stand and site impacts. Forest Products Journal. 45(5): 74–79.

Lanford, Bobby L.; Stokes, Bryce J. 1996. Comparison of two thinning systems. Part 2. Productivity and costs. Forest Products Journal. 46(11/12): 47–53.

LeDoux, Chris B.; May, Dennis M.; Johnson, Tony; Widmann, Richard H. 1995. Assessing the feasibility and profitability of cable logging in the southern upland hardwood forests. Southern Journal of Applied Forestry. 19(2): 97–102.

May, Dennis M.; LeDoux, Chris B. 1992. Assessing timber availability in upland hardwood forests. Southern Journal of Applied Forestry. 16(2): 82–88.

McDonald, T.P.; Stokes, B.J.; Aust, W.M. 1995. Soil physical property changes after skidder traffic with varying widths. Journal of Forest Engineering. 6(2): 41–50.

McDonald, Tim; Carter, Emily; Taylor, Steve; Torbert, John. 1998. Relationship between site disturbance and forest harvesting equipment traffic. In: Proceedings of the second southern forestry GIS conference. Athens, GA: University of Georgia: 85–92.

Miller, James H.; Sirois, Donald L. 1986. Soil disturbance by skyline yarding vs. skidding in a loamy hill forest. Soil Science Society of America Journal. 50(6): 1579–1583.

Mooney, Scott T.; Boston, Kevin D.; Greene, W. Dale. 2000. Production and costs of the Chambers Delimbinator in first thinning of pine plantations. Forest Products Journal. 50(4): 81–84.

TIMBER

Moulton, Robert J. 1999. Tree planting in the United States—1997. Tree Planter's Notes. 49(1): 5–15.

Munn, Ian A.; Cutshall, Jason B.; Hodges, Donald G. 1998. 1993 pulpwood logging contractor survey. Forest Products Journal. 48(7/8): 47–53.

North Carolina State Forest Nutrition Cooperative. 1999. North Carolina State forest nutrition cooperative; 29th annual report. Raleigh, NC: North Carolina State University, Department of Forestry. 20 p.

Plantinga, Andrew J. 1998. The optimal timber rotation: an option value approach. Forest Science. 44(2): 192–202.

Prestemon, Jeffrey P.; Pye, John M.; Abt, Karen Lee [and others]. 2000. Market definition for hardwood timber in the Southern Appalachians. In: Munn, I.A.; Bullard, S.H.; Grado, S.C.; Grebner, D.L., [eds.]. Proceedings of the 1999 southern forest economics workshop. Starkville, MS: Mississippi State University: 91-98.

Reisinger, T.W.; Simmons, Gerry L.; Pope, Phillip E. 1988. The impact of timber harvesting on soil properties and seedling growth in the South. Southern Journal of Applied Forestry. 12(1): 58–67.

Rosenberg, Nathan; Ince, Peter; Skog, Kenneth; Plantinga, Andrew. 1990. Understanding the adoption of new technology in the forest products industry. Forest Products Journal. 40(10): 15–22.

Row, Clark. 1978. Economies of tract size in timber growing. Journal of Forestry. 76(9): 576–582.

Rummer, Bob. 1998. The effect of shelterwood prescriptions on forest operations productivity. Pap. 98–7017. St. Joseph, MI: American Society of Agricultural Engineers. 8 p.

Rummer, R.B.; Sirois, D.L. 1984. A preliminary assessment of the productivity and site impacts of skidders operating on steep terrain. Pap. 84–1616. St. Joseph, MI: American Society of Agricultural Engineers. 17 p.

Seixas, Fernando; McDonald, Tim. 1997. Soil compaction effects of forwarding and its relationship with 6- and 8-wheel drive machines. Forest Products Journal. 47(11/12): 46–52.

Seixas, Fernando; McDonald, Tim; Stokes, Bryce J.; Raper, Randy L. 1995. Effect of slash on forwarder soil compaction. In: Proceedings of the 18th annual meeting of the Council on Forest Engineering. Corvallis, OR: Council on Forest Engineering: 77–86.

Seixas, Fernando; Stokes, Bryce; Rummer, Bob; McDonald, Tim. 1995. Harvesting soil impacts for selected silvicultural prescriptions. In: The way ahead with harvesting and transportation technology: Proceedings of the IUFRO P3.07 meeting. Vienna, Austria: International Union of Forestry Research Organizations: 230–238.

Sirois, Donald L.; Stokes, Bryce J. 1986. Helicopter used in swamp logging. Tech. Release 86–R–22. Washington, DC: American Pulpwood Association. 2 p.

Sloan, Hank; Tollenaere, John; Croff, Chris. 1994. Technology advances in helilogging: a case study of the K-MAX in Appalachian hardwoods. In: Applied ecology in action: Proceedings of the 17th annual meeting of the Council on Forest Engineering. Corvallis, OR: Council on Forest Engineering: 237–245.

Stokes, Bryce J. 1991. New harvesting developments in Southern U.S.A. In: Raymond, Keith, ed. Proceedings of the logging industry research organization seminar: machinery developments in logging. Rotorua, New Zealand: LIRO: 1–10.

Stokes, Bryce J.; Rummer, Bob. 1997. Innovative harvesting systems in bottomland hardwoods. In: Proceedings of the 25th annual hardwood symposium. Memphis, TN: National Hardwood Lumber Association: 99–102.

Stokes, Bryce J.; Rummer, Robert B.; Klepac, John. 1998. Production and site impacts of wide-tired skidding on steep slopes. Pap. 98–7029. St. Joseph, MI: American Society of Agricultural Engineers. 30 p.

Stokes, Bryce J.; Watson, William F. 1996. Plantation thinning systems in the Southern United States. In: Mitchell, Paul; Stevens, Eric; Kofman, Pieter, eds. Problems and prospects for managing cost-effective early thinnings: a report from the concerted action: cost-effective early thinnings. AIR2–CT93–1538. Horsholm, Denmark: Danish Forest and Landscape Research Institute: 107–121.

Stuart, W.B.; Grace, L.A. 1999. Wood supplier productivity and cost survey. Final report 99–A–7. Rockville, MD: American Pulpwood Association. 51 p.

Stuart, William B.; Carr, Jeffrey L. 1991. Harvesting impacts on steep slopes in Virginia. In: Proceedings of the eighth central hardwood conference. Gen. Tech. Rep. NE–148. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 67–81.

Thompson, Michael T.; Johnson, Tony G. 1996. A forested tract-size profile of Virginia's NIPF landowners. Res. Pap. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 8 p.

Toms, Christopher W. 1999. Whoa, mule: animal-powered logging in Alabama at the end of the twentieth century. Auburn, AL: Auburn University. 75 p. M.S. thesis.

Toms, Christopher W.; Bliss, John C.; Wilhoit, John H.; Rummer, Robert B. 1998. Horse and mule logging in Alabama: a forest management tool for the future? In: Integrating environmental values into small-scale forestry. Vancouver, CA: International Union of Forestry Research Organizations. [Number of pages unknown].

Toms, Christopher W.; Wilhoit, John H.; Rummer, Robert B. 1996. Animal logging in the Southern United States. Pap.96–5005. St. Joseph, MI: American Society of Agricultural Engineers. 13 p.

U.S. Census Bureau. 2000a. Annual survey of manufactures. [Database]. http://tier2.census.gov/dbappweb.htm. [Last accessed December 31].

U.S. Census Bureau. 2000b. Occupation data. [Database]. http://tier2.census.gov/dbappweb.htm. [Last accessed: December 31].

U.S. Department of Labor, Bureau of Labor Statistics. 2000a. Covered employment and wages. http://stats.bls.gov/help/def/ew.htm. [Date accessed: December 31].

U.S. Department of Labor, Bureau of Labor Statistics. 2000b. Producer price indexes. http://stats.bls.gov/ppi/home.htm. [Date accessed: January 16, 2001].

Vidrine, Clyde G.; deHoop, Cornelis; Lanford, Bobby L. 1999. Assessment of site and stand disturbance from cut-to-length harvesting. In: Haywod, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 288–292.

Waldrop, Thomas A. 1997. Four site-preparation techniques for regenerating pine-hardwood mixtures in the Piedmont. Southern Journal of Applied Forestry. 21(3): 116–122.

Watson, W.F.; Twaddle, A.A.; Stokes, B.J. 1991. Quality of chips produced with chain flails and woodland chippers. Tappi Journal. 74(2): 141–145.

Willingham, Phil. 1989. Wetland harvesting systems for the Mobile Delta. In: Proceedings of the southern regional council on forest engineering. Auburn, AL: Southern Regional COFE: 148–151.

Worthington, Virginia E.; LeDoux, Chris B.; McWilliams, William H. [and others]. 1996. Methodology for assessing current timber supplies and product demands. Gen. Tech. Rep. NE–226. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 25 p.

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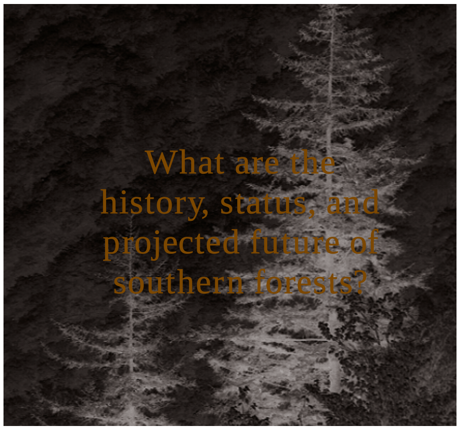

Chapter 16:
Forest Area and Conditions

(Revised Dec. 3, 2002)

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Key Findings

- Area of timberland has increased by 5 million acres during the past 10 years. Since 1952 the area of hardwoods and oak-pine has increased while pine area has decreased.
- In 1952, natural pine stands occupied 72 million acres and planted pines covered 2 million acres, or 1 percent of the timberland area in 12 of the 13 Southern States. By 1999, planted pine stands occupied 48 percent of the area of pine in the region.
- Urbanization surpassed agriculture as the primary cause of loss of forest land in 1984. As of 1987, the South began gaining forest land faster than it was being lost. By 1990, annual gains in forest land amounted to 1.3 million acres, while diversions of forest land to other uses amounted to 841,000 acres.
- Timberland owned by forest industry declined for the first time between 1989 and 1999. Private corporate ownership rose from less than 16 million acres in 1982 to nearly 20 million acres in 1999, partly due to increased holdings by Timber Investment and Management Organizations (TIMOs). "Pure" TIMOs controlled 4.2 million acres, or 2 percent of the South's timberland area in 1999 (chapter 14).
- Between 1953 and 1999, total growing-stock volume rose 72 percent, while average annual growth and mortality went up 60 percent and 130 percent, respectively. Average annual removals of growing-stock have risen 52 percent since 1982.
- As of 1999, nonindustrial private forest (NIPF) landowners controlled 71 percent of the timberland area; they have held at least 70 percent of the total growing-stock volume since 1953.
- Planted stands accounted for only 11 percent of the region's total growing-stock volume in 1999, but contributed 41 percent of the softwood net annual growth and 29 percent of annual softwood removals.
- Average annual removals of softwood growing stock exceeded average annual growth for the first time in 1999. However, softwood growth should rise once trees on 21 million acres of softwood saplings/seedlings stands reach growing-stock size and begin contributing to estimates of net annual growth.

Introduction

The South has 215 million forest acres, which represent 29 percent of the forest land in the United States. This estimate of forest land includes reserved areas, woodlands, and "commercial forest land," which is now referred to as productive timberland.

The pine and hardwood stands of today differ markedly from those that were here 100 and 200 years ago, and the changes continue. The importance of forests and the changes that were occurring in them led Congress in 1928 to pass the McSweeney-McNary Act, creating Forest Survey Units in the USDA Forest Service and laying the foundation for a nationwide forest inventory system. Now called Forest Inventory and Analysis (FIA), Forest Survey in the South began in the bottomlands of the Mississippi Delta in 1932 (Frayer and Furnival 1998). By 1933, the initial inventories of the pine forests of south Georgia and north Florida were well underway (Knight 1972); and by 1940, the first forest inventories of Florida, Georgia, North and South Carolina, and Virginia were complete. Kentucky and Tennessee were the only Southern States where an inventory had yet to begin. Kentucky, first inventoried in 1949 as part of the Northeastern States survey, became the responsibility of the southern FIA in 1995. The initial inventory of Tennessee was completed in 1950.

After World War II, the second round of Southern State inventories began, and subsequent surveys in the South have followed at roughly 10-year intervals. Since the beginnings of Forest Survey, every State in the South (except Kentucky) has been inventoried at least six times. Today, seventh or eighth inventories are underway in 12 Southern States, and Kentucky is being inventoried for the fifth time.

Because timber supply was then the primary concern, the early Forest Survey efforts focused on determining the amount of wood volume available at the time. Through the years, inventory procedures have been revised many times as new sampling designs and methods were tested and adopted. The early line-plot method gave way to fixed-area samples, which were dropped in favor of variable-radius sampling in the late 1950s. The current forest inventory methodology is a mapped-plot design, used for the first time during the 1997 inventory of Georgia and for the 1999 survey of

Tennessee. In addition to using a new sampling design, FIA in the South is currently changing from its traditional periodic inventories to an annual forest inventory system.

As survey methods changed over the years, so did the scope of the inventories. The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 broadened the responsibilities of FIA to include all renewable resources on the Nation's forests and rangelands. In addition to the traditional timber-related data, this new "multiresource" inventory began collecting information on recreation, wildlife habitat, forested range, soil, and water (Van Hooser and others 1992).

This chapter describes the changes and trends in southern forests over the past 50 to 100 years, primarily based on FIA statistics. Analyses focus on the amount and distribution of timberland area by stand age, forest type, stand size, and ownership, as well as on changes in volume, growth, mortality, and removals of timber.

Methods

Summaries of data published in the 2001 RPA report (Smith and others 2001) were used to examine the early history of land use and management of forest land in the South. The RPA estimates for the earliest years are taken from a variety of historical accounts, observations, and initial timber resource reports. More recent data are taken from summaries of statewide inventories conducted by FIA.

Pre-European Settlement Up to the 1930s

Historical descriptions of the extent and condition of southern forests present at this time come from anecdotal accounts and observations. This information covers the period from pre-European settlement up to the 1930s, the beginning of forest inventories in the South. Estimates of forest land area for the years 1630 and 1907 were taken from the 2001 RPA report (Smith and others 2001).

1930s to 1970s: The Early FIA Inventories

Sources of initial inventory data collected and summarized for each State by FIA between 1934 and 1950 are published statistical and analytical reports. However, subsequent changes in sampling design and methods, standards, and definitions make the FIA data from these initial inventories largely incompatible with results of later inventories. The results of the early inventories are limited to published estimates of forest land area, timber volume, and a few other variables. The 1938 resource estimates, taken from the 2001 RPA report, were used to represent the period between 1934 and 1950. Resource data for the 1950s to the 1970s also come from the 2001 RPA report, specifically for the years 1953 and 1963. RPA estimates for 1953 and 1963 are essentially summaries of past FIA statewide inventories, updated in some cases to a common year.

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Table 16.1—Area of forest land by State and year, Southern United States

	Year							
State	1630[a]	1907[a]	1938[a]	1953[a]	1963[a]	1982[b]	1989[c]	1999[d]
	Thousand acres							
Alabama	29,540	20,000	18,878	20,771	21,770	21,375	21,725	21,965
Arkansas	31,940	24,200	20,963	19,681	20,051	17,139	17,687	18,790
Florida	29,840	24,128	21,740	20,817	19,050	17,134	16,549	16,221
Georgia	35,700	22,300	21,433	24,057	26,365	24,243	24,137	24,413
Kentucky	23,140	10,000	11,546	11,647	11,791	12,161	12,256	12,699
Louisiana	26,160	16,500	16,211	16,230	16,176	14,529	13,883	13,792
Mississippi	26,700	17,500	16,253	16,890	17,076	16,716	16,993	18,595
North Carolina	29,630	19,600	18,400	20,113	20,662	20,025	18,953	19,278
Oklahoma	13,330	10,500	10,415	10,329	9,235	8,513	7,283	7,665
South Carolina	17,570	12,000	10,704	11,943	12,250	12,575	12,257	12,646
Tennessee	24,010	15,000	13,000	12,808	13,629	13,360	13,603	14,405
Texas	41,980	30,000	26,949	24,708	23,954	23,279	20,505	18,354
Virginia	24,480	14,000	14,832	16,032	16,412	16,417	15,968	16,027
Total	354,020	235,728	221,324	226,026	228,421	217,465	211,799	214,848

Numbers in columns may not sum to totals due to rounding.
[a] Data from Smith and others 2001.
[b] Data for 1982 are based on FIA inventories conducted between 1972 and 1982, except for Kentucky, Oklahoma, and Texas. Data for these three States are taken from Smith and others 2001.
[c] Data for 1989 are based on inventories conducted by FIA between 1982 and 1989, except for Kentucky, Oklahoma, and Texas. Data for these three States are taken from Smith and others 2001.
[d] Data for 1999 are based on FIA inventories conducted between 1990 and 1999, except for Oklahoma and Texas. Data for these two States are taken from Smith and others 2001.

1970s to 1999

The bulk of the results and discussion of southern forests in this chapter are based on analyses of FIA data collected since the 1970s. FIA data collected over the past three decades are compatible and consistent and allow for general comparisons and analyses of trends in forest area, volume, growth, mortality, and removals. Differences in sampling methods and changes in design, standards, and definitions are noted. Definitions of FIA data variables are included in the report glossary. A general description of the sampling designs and methods used by FIA to conduct the past three statewide inventories is provided at the end of this chapter.

Analyses were based on data for all 13 States aggregated into three "report" years—1982, 1989, 1999—using the past three surveys of each State:

State	Report year		
	1982	*1989*	*1999*
AL	1972	1982	1990
AR	1978	1988	1995
FL	1980	1987	1995
GA	1982	1989	1997
KY	1975	1975	1988
LA	1974	1984	1991
MS	1977	1987	1994
NC	1974	1984	1990
OK	1976	1986	1993
SC	1978	1986	1993
TN	1980	1989	1999
TX	1975	1986	1992
VA	1977	1986	1992

The 1982 report year includes data for States inventoried between 1972 and 1982, including the 1975 survey of Kentucky. The 1989 report year, with the exception of Kentucky, includes State surveys conducted between 1982 and 1989. In order to include Kentucky and provide analyses for the entire South, data from the 1975 inventory were used to represent both the 1982 and 1989 report years. In a few cases where the 1975 FIA data for Kentucky were not available, estimates from the 2001 RPA report were used. The 1999 report year includes surveys conducted between 1990 and 1999, again with the exception of Kentucky. The most recent inventory of Kentucky, completed in 1988, was used to represent the 1999 report year.

Data Sources

The FIA data discussed in this chapter are from published reports and from extensive databases residing at the Southern Research Station's FIA Work Units in Knoxville, TN, and Starkville, MS. Additional data come from the 2001 RPA report (Smith and others 2001). Decadal RPA assessments, based on data collected by FIA units, have been published since the 1970s and provide trends and current status in key resource variables. Data from the *South's Fourth Forest* (U.S. Department of Agriculture Forest Service 1988) report also were used to describe past use and management and track more recent trends in southern forest resources. Additional information was gathered from published literature that is cited appropriately.

In an attempt to use the latest data available, any additional statewide inventories completed and published during the analysis phase of the study also will be included. It will not be possible to include these data in the tables and graphics for this chapter; however, they will be used to analyze the latest changes and trends at the State level in the applicable States.

Results and Discussion

Changes in Forest Land Area in the South

Forest land, as defined by FIA, is at least 10-percent stocked by trees of any size or formerly having had such tree cover and is not currently developed for nonforest use. The minimum area considered for classification is 1 acre. Estimates of forest land include all reserved, woodland, and timberland acres in the 13 Southern States.

Although actual inventories of forest land in the United States did not begin until the 1930s, estimates of forest land for individual Southern States are available from RPA (Smith and others 2001) as far back as 1630 (table 16.1). These early estimates are based on the current area of forest land and on accounts of land clearing and settlement by Native Americans and European settlers. This "original forest" area is presented only for comparison with what remains today.

The area of forest land in the South has changed dramatically since European settlement. It is estimated that there were 354 million acres of forest land in 1630 (fig. 16.1). Descriptions and anecdotal accounts of the appearance of the forests at that time reveal a landscape very different from that which we see today (chapter 24). By 1907, the area of southern forests had declined by one-third to 236 million acres. Much of the decline was due to clearing for homes, crops, and pasture. The continued influx of people, the lack of a concerted effort to regenerate cleared forest land, and uncontrolled wildfires led to further declines over the next three decades, and by 1938 forests occupied 221 million acres.

The Civilian Conservation Corps, along with the Agricultural Conservation Program of the 1930s, and

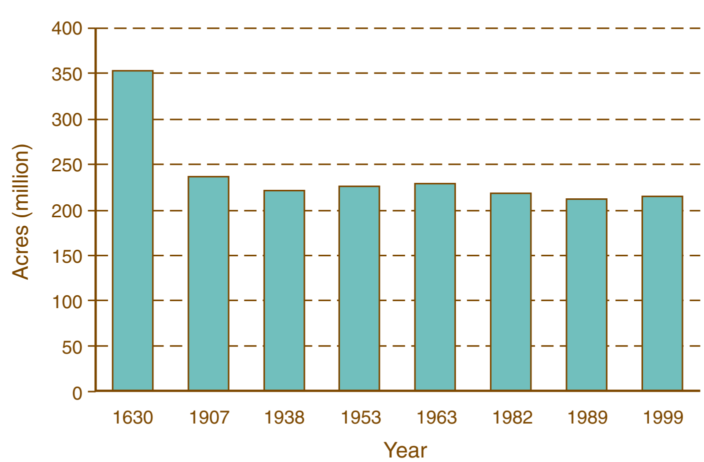

Figure 16.1—Forest area by year, Southern United States.

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the Soil Bank Program of the 1950s, helped return millions of acres of idle pasture and eroded cropland to forest (U.S. Department of Agriculture Forest Service 1988). Between 1938 and 1963, area of forest land in the South rose by 7 million acres to 228 million. This gain was short-lived, however, and by 1982 forest area dropped to 218 million acres, as 10 million acres of forest land were cleared for farming and development. The loss of forest land continued over the next 7 years, and the total area declined to a low of 212 million acres. To help reverse this latest downward trend, the Conservation Reserve Program was established in 1985. It provided farmers with monetary incentives to plant trees on highly erodible cropland. These incentives and other efforts apparently had the intended affect. By 1999, southern forest area had increased by 3 million acres to 215 million acres. However, since 1907 the South has lost nearly 21 million acres, or 9 percent of its forest land.

Diversions of forest land to agriculture and urbanization—Since the 1930s, FIA has tracked the changes in the area of forest land by classifying current and previous land use at each sample location. Acres that were previously forested but are now cleared for agriculture or developed for some other nonforest use are called diversions. Diversions to agriculture or an urban land use account for the majority of the losses of forest land in the South. Average annual diversion of forest land to these nonforest land uses between 1968 and 1990 are shown in figure 16.2. Data for figure 16.2 were compiled from published FIA reports on file at the Southern Research Station, Knoxville, TN. Data for Kentucky were not available.

The area of cropland and pasture peaked in the 1920s and has been declining since (U.S. Department of Agriculture Forest Service 1988). The reduced demand for agricultural land is reflected in the rate at which forest land was cleared for crops and related uses. In 1968, forest land was being converted to agriculture at the rate of 1.1 million acres per year (fig. 16.2). By 1990, the annual rate of conversion had declined to 308,000 acres.

In contrast, the rate of forest land lost to urbanization, until recently, has increased steadily, closely following the upward trend in the region's population (chapter 6). FIA estimates show that 377,000 acres of forest were lost to urban and other related land uses in 1968, and by 1978 the annual rate of loss had increased to 508,000 acres (fig. 16.2). By 1983 and 1984, urbanization was removing forest land from the South's timber base at an average rate of 540,000 acres per year, surpassing agriculture as the primary cause of loss of forest land. The rate of urbanization has declined in recent years, but in 1990 diversions of forest land to urban and related uses remained substantial, amounting to 406,000 acres. Cumulatively, forest land converted to agriculture or urban land uses during this 23-year period total 25 million acres. These figures likely include acres that have undergone more than one transition.

The fact that urbanization is apparently the primary reason for reductions in forest land holds important implications. Land clearing for crops and pasture is often transitory, as economics, owner goals, and other factors dictate land use over time. For instance, timberland acres originally cleared for cotton over 50 years ago are once again supporting stands of hardwoods and pine. The same cannot be said for diversions of forest land to urban land uses, which are usually permanent.

Total change in forest land: additions and diversions—While losses to urbanization and agriculture were occurring, there were also concerted efforts throughout the South to regenerate nonforest land. Figure 16.3 shows the average annual change in total area of forest land in the South between 1970 and 1990. Total diversions include the acres of forest land converted to water, plus the diversions to agricultural or urban and other land uses already discussed. The primary source of additions to forest land is idle cropland or pasture, which regenerated naturally or was planted or seeded.

Average annual diversions to nonforest decreased steadily between 1970 and 1990, but they consistently outpaced the rate of additions (fig. 16.3). In 1970, total diversions removed 1.8 million acres from the timber base. Additions amounted to 787,000 acres, and the South experienced an average net loss of over 1 million acres of forest in that year. The rate at which nonforest was being regenerated reached a peak in

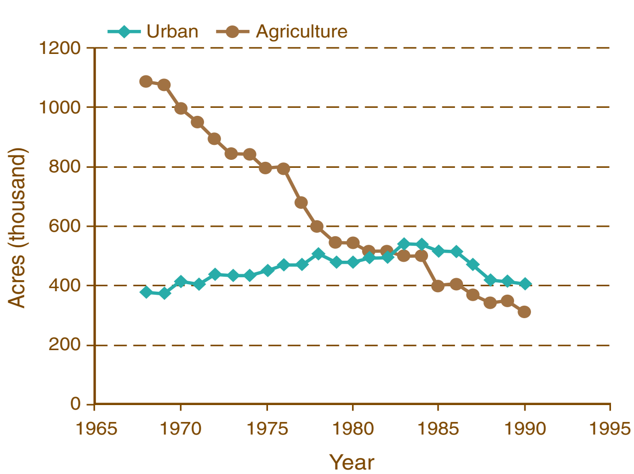

Figure 16.2—Average annual diversions of forest land to agriculture and urban land uses, Southern United States, 1968 to 1990 (excludes Kentucky).

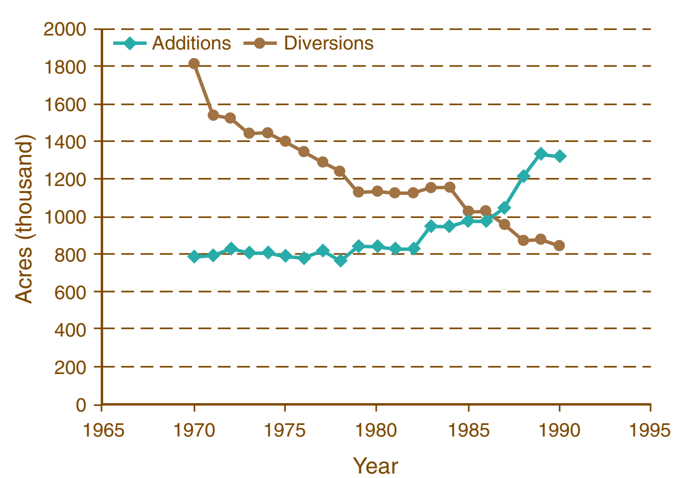

Figure 16.3—Average annual change in area of forest land in the Southern United States, 1970 to 1990 (excludes Kentucky).

1972 at 829,000 acres. The annual rate of additions declined over the next 6 years, and the 1972 level was not surpassed until 1979 and 1980, when 839,000 acres were reforested annually. Cumulatively, 9 million acres of forest land were added between 1970 and 1980. The annual rate of diversions continued to slow, but still exceeded additions. By 1980, a total of 15 million acres of forest land had been diverted to a nonforest classification, resulting in a net loss of 6 million acres region-wide over the 10-year period. The gap between the rates of diversion and additions was closing, however. Evidence suggests that Federal Government initiatives, such as the Forestry Incentives Program of the 1970s, were helping to slow the rate of deforestation and increase the rate of planting and reseeding on cleared and other nonforest land.

From 1980 to 1986, the average annual rate of diversions remained fairly stable at around 1 million acres. Annual additions to forest land rose from 839,000 acres in 1980, to 972,000 acres by 1986. Cumulative losses of forest since 1980 amounted to 6.6 million acres, but additions totaled 5.5 million acres, for a net loss of 1.1 million acres over the period. There also is evidence that the more recent Federal incentives, such as the Conservation Reserve Program established in 1985, have helped slow the rate of diversion. A milestone was reached in 1987 when the South gained more forest land than it lost. That year, 1 million acres were added to the timber base, while 953,000 acres were diverted to other uses. By 1990, nonforest land was being converted to forest at a rate of 1.3 million acres, and diversions out of the timber base declined to 841,000 acres annually. Cumulative additions over the last 4 years of the period amount to 4.9 million acres, and diversions totaled 3.5 million acres.

The most recent year in which the additions/diversions data collected by FIA are available for each State is 1990. Current and future inventories will provide additional data to track the changes and trends in the South's forest land area in all 13 States. However, the increase of 3 million acres of forest between 1989 and 1999 shown in figure 16.1 suggests that the general trend in additions and diversions witnessed between 1987 and 1990 has continued over the past decade.

Changes and Trends in Timberland Area

Timberland, formerly called commercial forest land, is the primary component of forest land and is defined by FIA as forested acres capable of producing at least 20 cubic feet of industrial wood per year and not withdrawn from timber utilization. Figure 16.4 shows trends in total timberland area since 1953, along with estimates for reserved and other forest land. "Other forest land" is forested land that does not meet the minimum standard of productivity to be classified as timberland and land primarily stocked with tree species that are typically of poor form and quality. Examples of other forest land are the slow-growing "hatrack" cypress stands, the mangrove thickets in south Florida, and "scrub oak" and hickory on marginal sites in Oklahoma, Texas, and other Southern States. Reserved forest land includes State and National Parks, Monuments, Wilderness Areas, and other forested areas set aside by law or administrative designation. The reserved area estimates were taken from the 2001 RPA report (Smith and others 2001). These estimates include acres previously classified as unproductive reserved and include the western portions of Oklahoma and Texas, areas that traditionally were not inventoried by FIA. Therefore, the reserved and other forest land estimates in figure 16.4 will be higher than those reported by FIA.

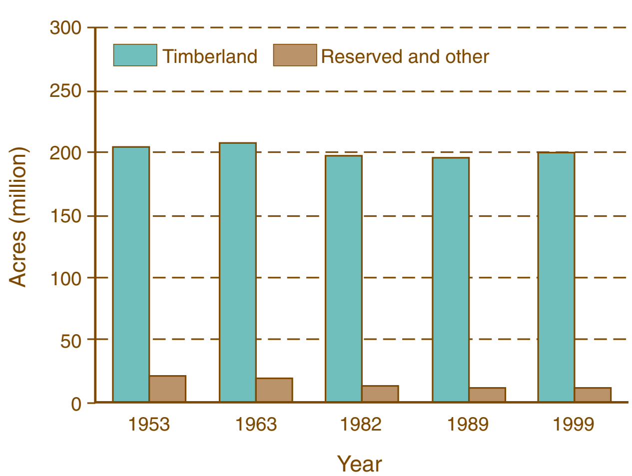

Figure 16.4—Total timberland area, and reserved and other forest land by year, Southern United States.

The area of timberland reported in 1953 amounted to 205 million acres. Timberland area peaked a decade later at 209 million acres. Some of this increase was due to a reclassification of other forest land to timberland. By 1989, timberland had declined to 196 million acres—a 4-percent drop since 1953 and a 6-percent decline from 1963. This was the low point in area of timberland. Over the past 10 years, timberland has increased to 201 million acres, largely due to the establishment of planted pine and planted oak-pine stands on nonforest land. The area of reserved and other forest land has decreased steadily, from 22 million acres in 1953 to less than 13 million acres in 1989 and 1999. Again, the reclassification of other forest land to timberland accounted for most of the decline.

Changes and trends in timberland area by State—Changes in area of timberland between 1953 and 1999 for individual States are shown in figure 16.5. Nearly all Southern States experienced both gains and losses of timberland during this period. The few exceptions are Florida and Louisiana, which have consistently lost timberland, and Kentucky, which is the only State to register gains in timberland area in successive inventories since 1953.

Florida has lost the most timberland, primarily due to urbanization. Since 1953, timberland area in the State has declined 19 percent to less than 15 million acres in 1999. Louisiana has lost more than 2 million acres of timberland over the past 46 years, but area has remained fairly stable during the past decade at about 14 million acres. Louisiana's timberland

Table 16.2—Area of timberland by State, year, and ownership class, Southern United States

State	Year[a]	All owner-ships	Public: Total public	Public: Federal: Total Federal	Public: Federal: National forest	Public: Federal: Other	Public: State	Public: County and munic-ipal	Private: Total private	Private: Forest industry	Private: Non-industrial private
		Thousand acres									
Alabama	1953	20,756	968	791	616	175	150	27	19,788	3,138	16,650
	1963	21,744	1,003	800	630	170	157	46	20,741	3,818	16,923
	1982	21,358	1,003	812	626	186	140	51	20,355	4,204	16,151
	1989	21,659	1,160	950	689	262	147	63	20,498	4,464	16,034
	1999	21,932	1,162	855	605	250	212	95	20,770	4,795	15,975
Arkansas	1953	19,627	2,916	2,799	2,292	507	115	2	16,711	4,157	12,554
	1963	19,971	2,856	2,651	2,385	266	194	11	17,115	4,007	13,108
	1982	16,707	3,011	2,659	2,329	330	311	41	13,696	4,258	9,438
	1989	17,245	3,077	2,679	2,298	382	342	55	14,168	4,364	9,804
	1999	18,392	3,296	2,835	2,372	463	394	67	15,096	4,497	10,599
Florida	1953	18,135	2,215	1,777	1,035	742	382	56	15,920	4,369	11,551
	1963	16,830	2,201	1,621	1,030	591	540	40	14,629	4,767	9,862
	1982	15,664	2,179	1,596	1,006	590	542	41	13,486	4,697	8,789
	1989	14,983	2,443	1,570	990	580	814	59	12,540	4,770	7,770
	1999	14,651	2,832	1,616	1,030	587	1,138	78	11,819	4,016	7,804
Georgia	1953	23,969	1,685	1,560	644	916	102	23	22,284	4,246	18,038
	1963	26,298	1,813	1,678	746	932	111	24	24,485	4,068	20,417
	1982	23,734	1,584	1,396	765	631	118	70	22,150	4,964	17,186
	1989	23,631	1,645	1,371	752	620	186	88	21,986	4,990	16,995
	1999	23,796	1,751	1,380	711	669	260	112	22,045	4,381	17,664
Kentucky	1953	11,497	725	672	455	217	53	0	10,772	308	10,464
	1963	11,651	652	575	438	137	77	0	10,999	308	10,691
	1982	11,902	896	819	589	230	76	1	11,007	255	10,752
	1989	11,909	890	856	583	273	34	0	11,019	205	10,814
	1999	12,347	1,004	863	628	235	141	0	11,344	205	11,139
Louisiana	1953	16,039	848	666	535	131	177	5	15,191	3,166	12,025
	1963	16,036	883	704	575	129	174	5	15,153	3,032	12,121
	1982	14,518	1,183	772	640	132	405	6	13,335	3,770	9,565
	1989	13,873	1,325	828	615	212	330	168	12,547	3,603	8,944
	1999	13,783	1,311	804	569	235	300	207	12,472	3,898	8,573
Mississippi	1953	16,853	1,709	1,235	1,036	199	54	420	15,144	2,461	12,683
	1963	17,044	1,708	1,255	1,109	146	55	398	15,336	2,526	12,810
	1982	16,685	1,751	1,516	1,258	258	112	123	14,934	3,029	11,905
	1989	16,987	1,950	1,581	1,218	363	253	116	15,037	3,200	11,838
	1999	18,587	1,951	1,541	1,107	435	310	100	16,636	3,238	13,398
North Carolina	1953	19,584	1,541	1,252	1,020	232	253	36	18,043	2,584	15,459
	1963	19,989	1,663	1,290	1,033	257	307	66	18,326	2,495	15,831
	1982	19,545	1,745	1,347	1,011	336	320	78	17,800	2,135	15,665
	1989	18,450	1,922	1,509	1,117	393	332	80	16,529	2,337	14,191
	1999	18,710	2,003	1,572	1,082	490	347	84	16,708	2,252	14,456
Oklahoma	1953	5,075	494	309	213	96	185	0	4,581	889	3,692
	1963	4,892	427	291	223	68	136	0	4,465	865	3,600
	1982	4,316	478	356	196	160	116	6	3,837	967	2,870
	1989	4,741	628	508	243	265	114	6	4,114	1,046	3,068
	1999	4,895	637	498	223	275	118	21	4,259	1,047	3,212
South Carolina	1953	11,884	955	802	563	239	128	25	10,929	1,650	9,279
	1963	12,171	1,034	858	564	294	153	23	11,137	2,010	9,127
	1982	12,503	1,091	901	579	322	167	23	11,413	2,243	9,170
	1989	12,179	1,173	913	577	337	233	27	11,006	2,626	8,379
	1999	12,455	1,114	904	560	344	177	33	11,341	2,322	9,019

continued

Table 16.2—Area of timberland by State, year, and ownership class, Southern United States (continued)

			Public						Private		
				Federal							
State	Year[a]	All ownerships	Total public	Total Federal	National forest	Other	State	County and municipal	Total private	Forest industry	Nonindustrial private
		Thousand acres									
Tennessee	1953	12,551	1,114	806	564	242	298	10	11,437	713	10,724
	1963	13,365	1,199	834	591	243	344	21	12,166	923	11,243
	1982	12,959	1,375	966	585	381	379	30	11,585	1,226	10,359
	1989	13,265	1,509	1,027	556	471	422	59	11,756	1,122	10,635
	1999	13,965	1,568	981	557	424	519	69	12,397	1,393	11,004
Texas	1953	13,081	782	745	654	91	35	2	12,299	3,019	9,280
	1963	12,960	832	780	623	157	50	2	12,128	3,362	8,766
	1982	11,662	843	774	661	113	52	17	10,820	3,835	6,985
	1989	11,565	769	700	610	90	57	12	10,797	3,796	7,001
	1999	11,774	790	675	577	98	68	47	10,985	3,720	7,265
Virginia	1953	15,497	1,493	1,355	1,198	157	86	52	14,004	1,095	12,909
	1963	15,753	1,535	1,395	1,203	192	88	52	14,218	1,454	12,764
	1982	15,973	1,956	1,704	1,458	246	183	69	14,017	1,670	12,347
	1989	15,436	1,994	1,708	1,487	221	209	77	13,442	1,834	11,608
	1999	15,448	1,983	1,689	1,468	221	211	83	13,464	1,537	11,927
Total	1953	204,548	17,445	14,769	10,825	3,944	2,018	658	187,103	31,795	155,308
	1963	208,704	17,806	14,732	11,150	3,582	2,386	688	190,898	33,635	157,263
	1982	197,527	19,095	15,618	11,703	3,915	2,921	556	178,433	37,251	141,182
	1989	195,923	20,485	16,202	11,734	4,468	3,473	810	175,438	38,356	137,082
	1999	200,734	21,401	16,211	11,487	4,724	4,195	995	179,335	37,301	142,034

Numbers in rows and columns may not sum to totals due to rounding.
[a] All data for Kentucky are taken from Smith and others 2001, as are data for years 1953 and 1963. Data for 1982, 1989, and 1999 (except for Kentucky) are based on FIA inventories conducted between 1972-82, 1982–89, and 1990–99, respectively.

acres lost to agriculture, particularly in the Mississippi Delta, have stabilized. However, since the mid-1970s annual losses to urbanization have been on the rise.

Kentucky gained 412,000 acres of timberland between 1953 and 1989. The State's timberland area increased by another 438,000 acres to over 12 million acres by 1999. In all, only five States have more timberland area today than was estimated in 1953. However, all States, except Florida and Louisiana, have shown an increase in timberland over the past decade. Largest gains in area occurred in Mississippi, with the addition of nearly 2 million acres to its timber base since 1989, and Arkansas, where an additional 1 million acres are now forest land.

Alabama has been gaining timberland since 1982, and a just released inventory shows this trend continuing. The latest figures report an increase of 994,000 acres of timberland and place total timberland in the State at 22.9 million acres (Hartsell and Brown 2002).

South Carolina gained 276,000 acres between 1989 and 1999. This upward trend, however, seems to have ended according to new inventory estimates just published (Conner and Sheffield 2001b). Those figures show that a loss of 142,000 acres of timberland has occurred, reducing total timberland area to 12.3 million acres.

While North Carolina timberland increased over the last decade, statistics from a new inventory of timberland in the State's southern Coastal Plain may be an indication that this trend too has reversed. In that region, timberland declined by 187,000 acres as more acres were cleared for agricultural and urban land uses (Conner and Sheffield 2001a).

Trends in Ownership

Ownership is at the center of many current issues surrounding the South's forest land. FIA identifies and tracks ownership of every forested sample location by accessing county records. Changes in the patterns of landownership, the number and types of southern landowners, and their many and varied reasons for owning forest land are important factors affecting the past, present, and future condition of the region's forest resources.

The South's timberland is held by two broad owner groups—public or private. Public ownership has accounted for between 9 and 11 percent of the timberland acres in the 13 Southern States over the past 46 years. In 1999, 21 million acres, 11 percent, were publicly owned (table 16.2 and fig. 16.6). Public land includes national forests and other public timberland administered by State, county and municipal agencies, miscellaneous Federal agencies, and Native Americans. Timberland in the "other public" category totaled 7 million acres in 1953 and 10 million acres in 1999.

The USDA Forest Service managed 12 million acres of southern timberland in 1999. This figure has changed little in the last 40 years. Much of the area that

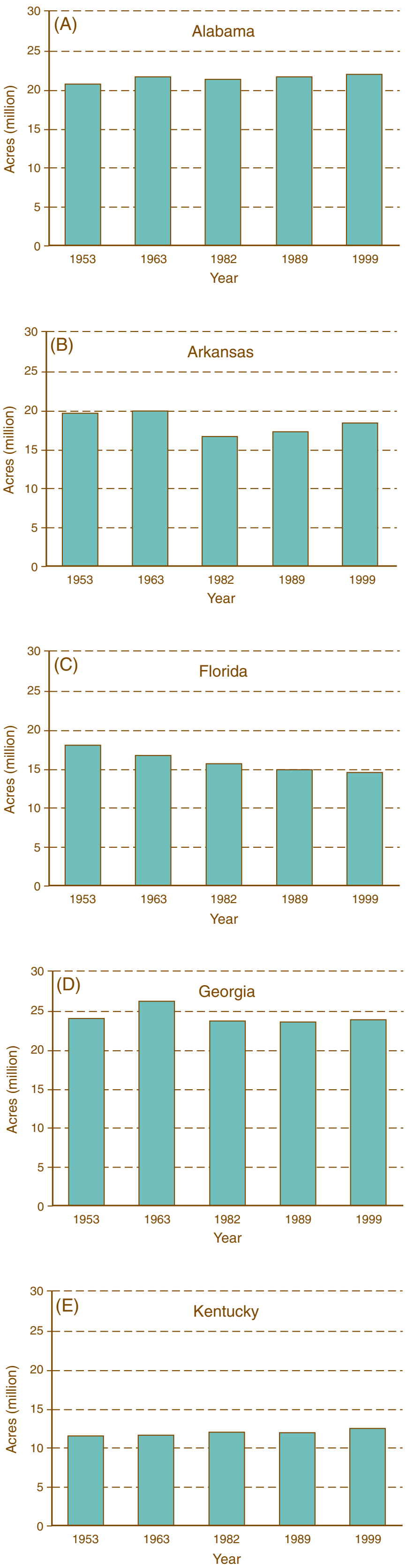

Figure 16.5—Trends in area of timberland by State and year, Southern United States.

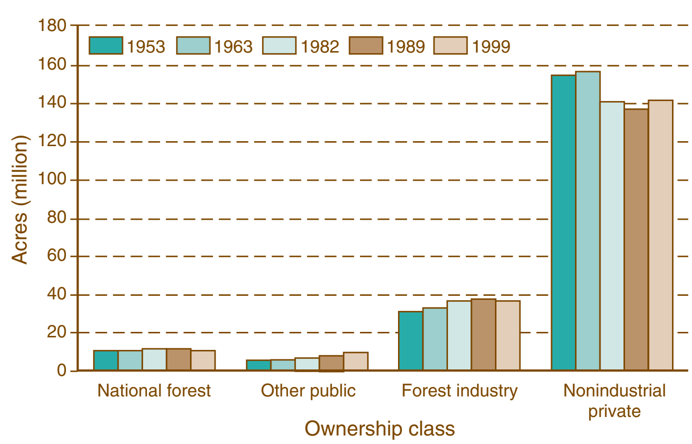

Figure 16.6—Timberland area by ownership class and year, Southern United States.

is now national forest was once cutover timberland and highly eroded cropland (Shands and Healy 1977). Legislative efforts to reclaim these areas began in 1907 with the establishment of the South's first national forest: the Ouachita National Forest in Arkansas and Oklahoma (U.S. Department of Agriculture Forest Service 2000). The reclamation efforts continued through the late 1930s with the purchase of national forest land in every Southern State. The last national forest created in the South was the Uwharrie established in North Carolina in 1961 (table 16.3). The National Forest System acreages reported in table 16.3 include nonforest land and are, therefore, higher than FIA estimates of national forest timberland.

Private landowners historically have held the lion's share of the South's timberland area. Private owners controlled 91 percent in 1953, and 89 percent remained in their hands in 1999. The two major groups of private owners are forest industry and nonindustrial private forest (NIPF) landowners.

Until recently forest industry acreage continually increased, from 32 million acres in 1953 to a peak of 38 million acres in 1989 (fig. 16.6). Industry ownership Southwide declined for the first time between 1989 and 1999, falling to 37 million acres. Florida and Georgia combined showed a decline of more than 1 million acres of industry timberland since 1989, and both South Carolina and Virginia registered substantial losses (table 16.2). Industry timberland is typically the most intensively managed and the most readily available source of raw material for the South's timber products industries. Therefore, even small declines in industrial ownership can have major impacts. However, much of what was previously forest industry timberland is now in the hands of private corporations. Many believe these corporate timberland acres will continue to be managed for wood products.

Indications from inventory data just released for Alabama (Hartsell and Brown 2002), South Carolina (Conner and Sheffield 2001b), and the southern Coastal Plain of North Carolina (Conner and Sheffield 2001a) are that the downward trend in forest industry timberland has continued beyond the 1999 report

Table 16.3—National forests by State, date established, original NFS acreage, and current NFS acreage, Southern United States

National forests by State	Date established	Original NFS acreage[a]	Current NFS acreage[b]
		Acres	*Acres*
Alabama			
Conecuh NF	7/17/1936	83,957	83,858
Talladega NF	8/31/1936	364,428	389,328
Tuskegee NF	11/27/1959	10,778	11,252
William B. Bankhead NF	1/15/1918	179,294	180,548
Total		638,457	664,986
Arkansas			
Ouachita NF[c]	12/18/1907	1,330,450	1,423,459
Ozark NF	3/6/1908	1,109,317	1,136,709
St. Francis NF	11/18/1960	20,946	21,201
Total		2,460,713	2,581,369
Florida			
Apalachicola NF	5/13/1936	557,729	565,543
Choctawhatchee NF	11/27/1908	1,152	1,152
Ocala NF	11/24/1908	367,204	383,573
Osceola NF	7/10/1931	157,230	158,255
Total		1,083,315	1,108,523
Georgia			
Chattahoochee NF	7/9/1936	741,279	749,352
Oconee NF	11/27/1959	104,511	115,231
Total		845,790	864,583
Kentucky			
Daniel Boone NF	2/23/1937	520,038	547,686
Jefferson NF[c]	4/21/1936	961	961
Total		520,999	548,647
Louisiana			
Kisatchie NF	6/10/1930	595,589	603,230
Total		595,589	603,230
Mississippi			
Bienville NF	6/15/1936	177,077	178,542
De Soto NF	6/17/1936	500,156	506,028
Delta NF	1/12/1937	59,159	60,015
Holly Springs NF	6/15/1936	145,141	155,661
Homochitto NF	7/20/1936	189,039	191,505
Tombigbee NF	11/27/1959	65,412	66,874
Total		1,135,984	1,158,625
North Carolina			
Cherokee NF[c]	7/14/1920	327	327
Croatan NF	7/29/1936	156,589	159,886
Nantahala NF	1/29/1920	457,772	527,709
Pisgah NF	10/17/1916	483,154	505,420
Uwharrie NF	1/12/1961	45,760	50,189
Total		1,143,602	1,243,531

continued

Table 16.3—National forests by State, date established, original NFS acreage, and current NFS acreage, Southern United States (continued)

National forests by State	Date established	Original NFS acreage[a]	Current NFS acreage[b]
		- - - - - - - - - - Acres	- - - - - - - - - -
Oklahoma			
Ouachita NF[c]	12/18/1907	244,489	350,845
Total		244,489	350,845
South Carolina			
Francis Marion NF	7/10/1936	249,406	252,288
Sumter NF	7/13/1936	357,599	360,868
Total		607,005	613,156
Tennessee			
Cherokee NF[c]	7/14/1920	618,494	634,198
Total		618,494	634,198
Texas			
Angelina NF	10/13/1936	155,293	153,180
Davy Crockett NF	10/13/1936	161,478	160,652
Sabine NF	10/13/1936	187,191	160,656
Sam Houston NF	10/13/1936	158,648	162,996
Total		662,610	637,484
Virginia			
George Washington NF[c]	5/16/1918	940,352	960,133
Jefferson NF[c]	4/21/1936	656,530	700,268
Total		1,596,882	1,660,401
Grand total		12,153,929	12,669,578

Numbers in columns may not sum to totals due to rounding.
NFS = National Forest System.
[a] Shands and Healy 1977.
[b] U.S. Department of Agriculture, Forest Service 2000.
[c] Unit is in two or more States.

year. Combined losses of forest industry timberland in these two States, and in North Carolina's southern coastal region amounted to 1.4 million acres. If declines of this magnitude hold for the remaining States, additional new inventories may reveal even further declines in industry timberland Southwide.

NIPF timberland owners hold more acres than any other owner group, public or private. This remains true even though their holdings declined between 1963 and 1989, reflecting the decline in total timberland area throughout the South. NIPF timberland, which amounted to as much as 157 million acres in 1963, declined to 137 million acres by 1989. In 1999, NIPF timberland was up to 142 million acres, an increase of 4 percent over the past decade.

Trends in nonindustrial private timberland—Private landowners often buy or sell timberland. Shifts in acres of timberland among NIPF landowners can have long-term effects on the extent, management, condition, and availability of southern forest resources.

Historically, the NIPF owner group included three ownership classes: farmers, corporations that do not manufacture forest products, and private individuals. However, beginning with the 1999 inventory of Tennessee, the farmer category was dropped; and these acres were included in the private individual owner class. To show general trends, the estimate of timberland owned by

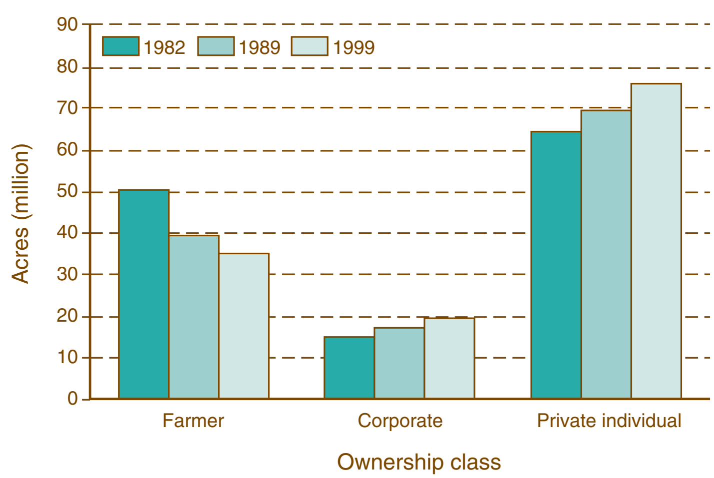

Figure 16.7—Trends in nonindustrial private timberland area by ownership class and year, Southern United States (excludes Kentucky). Previous estimate of timberland in Tennessee owned by farmers was used to represent the 1999 inventory.

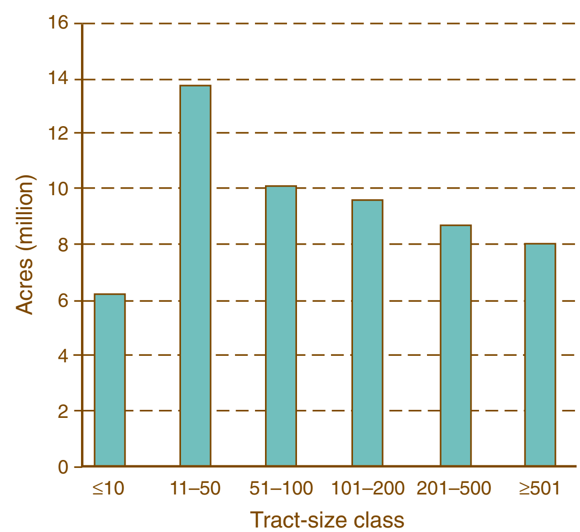

Figure 16.8—Area of nonindustrial private forest land by forested tract-size for the most recent surveys of Florida, Georgia, South Carolina, Tennessee, and Virginia.

farmers from the previous survey of Tennessee was used to represent the recent inventory.

Timberland under NIPF ownership in Kentucky amounted to 11 million acres in 1999 (table 16.2), but the distribution of this area among farmer, corporate, and individual ownerships was unavailable. Therefore, the trends shown in figure 16.7 do not include Kentucky.

Trends in nonindustrial private timberland since 1982 revealed increases in both corporate and individual ownership, accompanied by declines in timberland owned by farmers. The decline in farmer-owned timberland is a long-standing trend. In 1952, it is estimated that farmers held as much as 88 million acres, or two-thirds of the area of southern timberland (Healy 1985). Farmer-owned timberland declined over the next 30 years to about 51 million acres in 1982 (fig. 16.7). Recent estimates place farm ownership at just 35 million acres in 12 Southern States. Only Arkansas experienced a recent increase in farmer-owned timberland—rising 7 percent to 3 million acres between 1989 and 1999.

Corporate ownership rose from 16 million acres in 1982 to about 20 million acres in 1999. Recent additions to the corporate owner class are the timber investment and management organizations (TIMOs), which include banks, insurance companies, agribusiness, and realty investment and development firms. "Pure" TIMOs do not own timberland, but rather manage the land for private landowners. Numbers are difficult to determine due to differences in the definition of TIMOs, but one estimate showed 4 million acres of timberland in the South were in the hands of "pure" TIMOs in 1999 (chapter 14). Using a broader definition of TIMOs raises this estimate to nearly 8 million acres.

The outlook is for increased corporate investment in the South's timberland by TIMOs and similar companies. The rise in corporate timberland and the decline in timberland owned by forest industry is a recent trend seen in several Southern States (table 16.2). If this trend continues, corporate timberland will eventually play a larger role in the South's timber industry, perhaps offsetting the loss of acres owned by forest industry.

The final component of the NIPF owner class is private individuals. Individuals typically have owned the largest share of southern timberland and held 76 million acres in 1999. The 1999 estimate represents a 9-percent increase in timberland area held by private individuals since 1989 and an 18-percent increase since 1982.

Ownership, tract size, and the potential for forest fragmentation— One potential effect of an increase in the area of timberland owned by individuals is forest fragmentation—the breaking up of contiguous forest stands into smaller pieces due to clearing for agriculture and urban development (chapter 1). In 1990, FIA began collecting forested tract-size information for all nonindustrial private ownerships throughout the South (Thompson 1997, Thompson 1999, Thompson and Johnson 1996). Thompson defines forested tract size as the area of forest within a tract of land owned by a NIPF landowner. The total forested area within each tract can be a single contiguous stand, or the sum of two or more stands. This information will provide a baseline for measuring future trends. Changes in average forested tract size and estimates of the number of private forest landowners and parcels owned, as discussed by Wicker (chapter 9), can provide additional indicators of the potential for forest fragmentation.

To date, forested tract-size data have been collected in five Southern States—Florida, Georgia, South Carolina, Tennessee, and Virginia—containing 56 million acres of NIPF land. Estimates from recent inventories show 30 million acres of NIPF timberland in these States were forested tracts totaling 100 acres or less, including 20 million acres in tracts totaling 50 acres or less (fig. 16.8). Less than 8 million acres of private timberland were classified as forested tracts greater than 500 acres.

Among forest management types, pine plantations tend to be in larger tracts. Nearly half of the 7 million acres of pine plantation on NIPF timberland were forested tracts greater than 200 acres, and another 20 percent were tracts containing between 101 to 200 forested acres (table 16.4). Only 18 percent of planted pine stands were in tracts where forested acres totaled 50 acres or less. In contrast, roughly half of the timberland acres in all other management types were in tracts with 100 forested acres or less.

Additional State surveys will tell if the forested tract-size distribution of NIPF land in these five States is representative of the entire South. If so, then more than half of the South's nonindustrial private timberland is composed of tracts in which forest land amounts to less than 100 acres, and less than one-fifth of NIPF tracts contain more than 500 acres of forest. Smaller forested tracts hold implications for wildlife habitat, and affect resource management decisions (chapter 1). Studies have shown that the practicality of timber management declines as forested tract size decreases (Birch 1997, Birch and others 1982, Thompson 1997, Thompson 1999, Thompson and Johnson 1996), and that landowners with the fewest acres of forest land have the fewest management options (chapter 15).

Timberland Distribution, Composition, and Stand Structure

The South's physiography largely determines the distribution and composition of its forests. In general, hardwoods are dominant in the Mountains and much of the Piedmont Plateau, and softwoods predominate in the southern Coastal Plains. The composition and structure of southern timberlands can be described by the distribution of forest types, stand size and age, and stand origin. Forest types are based on the tree species forming a plurality of live-tree stocking. Stand size is based on the diameter distribution of all live trees in a stand, while stand age represents the age of the dominant and codominant trees in the stand. Stand origin identifies a stand as having been established through natural regeneration or through planting or seeding by humans.

Distribution of timberland area by forest type—Changes over the past 50 years have altered the extent and distribution of hardwood and softwood forest types throughout the South. Overall, area in hardwoods and oak-pine has been increasing, and the area in softwoods has been decreasing. In 1953, upland and lowland hardwood forest types combined accounted for 46 percent of the region's timberland, or 94 million acres (fig. 16.9 and table 16.5). In 1999, hardwood forest types

Table 16.4—Area of nonindustrial private timberland by State, survey date, forested tract-size class, and forest management type

State, survey date, and forested tract-size class	All types	Forest management type					
		Pine plantation	Natural pine	Oak-pine	Upland hardwood	Lowland hardwood	Nonstocked
Acres	- - - - - - - -	- - - - - - - -	- - - - - - - -	*Thousand acres*	- - - - - - - -	- - - - - - - -	- - - - - - - -
Florida 1995							
≤ 10	1,059	85	146	63	105	132	529
11–50	1,498	279	239	143	172	218	447
51–100	928	185	109	49	105	179	301
101–200	1,118	321	109	76	93	204	316
201–500	1,269	319	160	72	87	288	344
≥ 501	1,345	413	148	74	51	262	396
Total	7,217	1,602	910	476	613	1,283	2,333
Georgia 1997							
≤ 10	1,523	72	445	262	590	125	29
11–50	3,337	330	822	532	1,088	495	69
51–100	2,764	400	532	484	789	511	47
101–200	3,170	625	606	487	890	524	37
201–500	3,296	905	611	529	682	530	38
≥ 501	3,064	898	567	501	523	534	41
Total	17,154	3,232	3,584	2,795	4,562	2,720	262
South Carolina 1993							
≤ 10	891	30	195	108	277	109	171
11–50	2,217	176	476	360	512	339	355
51–100	1,610	271	363	230	262	245	239
101–200	1,469	251	326	217	267	203	205
201–500	1,305	241	305	186	149	243	181
≥ 501	1,456	241	365	169	159	276	246
Total	8,947	1,210	2,031	1,269	1,626	1,415	1,395
Tennessee 1999							
≤ 10	1,426	36	146	162	978	85	20
11–50	3,198	23	253	426	2,255	213	29
51–100	2,149	41	98	284	1,552	156	18
101–200	1,771	18	108	175	1,372	88	11
201–500	1,302	10	98	131	982	76	4
≥ 501	1,158	44	85	119	847	58	5
Total	11,004	171	789	1,297	7,986	675	86
Virginia 1992							
≤ 10	1,276	49	240	124	659	48	155
11–50	3,496	150	488	361	2,008	72	416
51–100	2,617	159	304	342	1,395	82	336
101–200	2,052	193	204	259	1,017	115	264
201–500	1,500	145	128	168	806	71	182
≥ 501	969	61	61	98	543	56	150
Total	11,910	757	1,427	1,350	6,428	445	1,503
Total							
≤ 10	6,175	272	1,173	718	2,609	500	903
11–50	13,745	958	2,278	1,821	6,033	1,338	1,316
51–100	10,068	1,055	1,407	1,388	4,103	1,173	941
101–200	9,579	1,408	1,353	1,214	3,638	1,133	833
201–500	8,672	1,621	1,303	1,085	2,707	1,208	749
≥ 501	7,993	1,657	1,226	961	2,123	1,187	838
Total	56,232	6,972	8,740	7,187	21,214	6,538	5,580

Numbers in rows and columns may not sum to totals due to rounding.
Source: Thompson 1997, 1999; and Thompson and Johnson 1996.

combined accounted for 52 percent of the South's 201 million acres of timberland. Oak-pine stands occupied 12 percent of the area in 1953 and 15 percent in 1999. Softwood forest types—principally longleaf-slash pine and loblolly-shortleaf pine—occupied 39 percent of the South's timberland area in 1953, but have accounted for less than one-third since 1982.

Most notable among the trends in softwood forest types is the continued decline in the area of longleaf-slash pine types. Longleaf pine is estimated at one time to have occupied 60 million acres in the Coastal Plain and Piedmont areas of the Atlantic Coast States (McWilliams and others 1997). By 1953, the combined area of longleaf-slash pine forest types had declined to 27 million acres. In 1999, area of longleaf-slash pine had been reduced to 13 million acres, and two-thirds of that area was in Florida and Georgia (table 16.6). Losses have continued to mount as acreage of longleaf-slash pine types declined by a total of 188,000 acres in Alabama and South Carolina according to latest inventory statistics (Conner and Sheffield 2001b, Hartsell and Brown 2002).

Loblolly-shortleaf pine forests have accounted for about one-fourth of the South's timberland area since 1953 (fig. 16.9), despite a steady decline in actual acreage—from 52 million acres to a low of 46 million acres in 1989 (table 16.5). The area of loblolly-shortleaf increased to 50 million acres by 1999 and still accounted for one-quarter of the South's timberland area.

The white-red-jack pine forest-type group occupied 688,000 acres in 1999, up from 551,000 acres in 1989. This national standard type-group is somewhat of a misnomer in the South. While white pine is a component of red and jack pine forest types in more northerly climes, in the South this forest-type group is composed almost entirely of white pine forest types.

Upland hardwoods—oak-hickory and maple-beech-birch forest types—accounted for 37 percent of the timberland area in 1999. The area of oak-hickory increased steadily between 1953 and 1999, from 55 million acres to 74 million acres (table 16.5). Oak-hickory timberland increased in 9 of the 13 Southern States since 1982, including the addition of 2 million acres in Alabama (table 16.6). Maple-beech-birch forest types increased

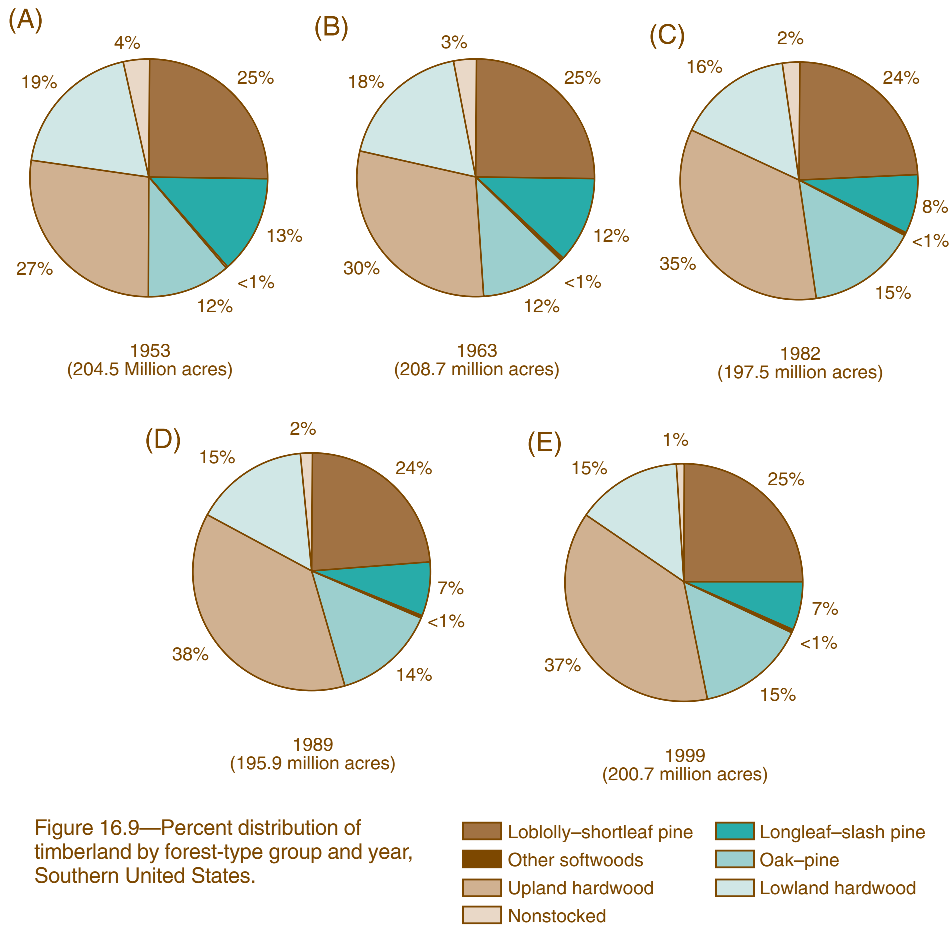

Figure 16.9—Percent distribution of timberland by forest-type group and year, Southern United States.

Table 16.5—Area of timberland by year and forest-type group, Southern United States

Year[a]	All groups	White-red-jack pine	Spruce-fir	Longleaf-slash pine	Loblolly-shortleaf pine	Oak-pine	Oak-hickory	Oak-gum-cypress	Elm-ash-cottonwood	Maple-beech-birch	Non-stocked
		Forest-type group									
		Thousand acres									
1953	204,546	329	12	26,926	51,792	23,970	54,872	34,498	4,051	750	7,346
1963	208,703	439	15	24,902	52,201	24,310	61,801	34,747	3,461	566	6,261
1982	197,525	453	8	15,926	47,766	29,556	67,752	27,613	3,082	996	4,374
1989	195,916	551	19	14,594	46,277	27,964	72,534	26,724	2,868	877	3,510
1999	200,736	688	13	13,176	49,797	29,875	74,027	28,093	2,533	1,015	1,522

Numbers in rows may not sum to totals due to rounding.

[a] Data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively. Kentucky data for 1999 are from the 1988 FIA survey, and data for both the 1982 and 1989 reporting years are from the 1975 FIA survey of Kentucky.

Table 16.6—Area of timberland by State, year, and forest-type group, Southern United States

State	Year[a]	All groups	White-red-jack pine	Long-leaf-slash	Loblolly-short-leaf	Oak-pine	Oak-hickory	Oak-gum-cypress	Elm-ash-cotton-wood	Maple-beech-birch	Non-stocked
		Forest-type group									
		Thousand acres									
Alabama	1982	21,358	—	1,512	6,499	5,081	5,650	2,479	23	—	114
	1989	21,659	—	1,409	5,819	4,426	7,415	2,456	40	—	95
	1999	21,932	5	1,187	6,255	4,522	7,650	2,253	16	—	44
Arkansas	1982	16,707	—	—	4,304	2,995	6,568	2,681	144	—	16
	1989	17,245	—	—	4,192	3,039	7,269	2,575	158	—	11
	1999	18,392	—	—	5,077	3,137	7,127	2,791	227	—	32
Florida	1982	15,664	—	6,024	1,163	1,320	1,240	3,846	61	—	2,011
	1989	14,983	—	5,743	1,330	1,116	1,114	3,826	84	—	1,772
	1999	14,651	—	5,621	1,554	1,463	1,981	3,562	42	—	428
Georgia	1982	23,734	81	4,595	6,557	2,922	5,448	2,990	447	—	694
	1989	23,631	74	4,048	6,794	3,048	5,582	3,109	312	—	663
	1999	23,796	85	3,403	7,153	3,567	5,421	3,555	222	1	390
Kentucky	1982	11,902	14	—	679	800	9,169	82	628	514	15
	1989	11,902	14	—	679	800	9,169	82	628	514	15
	1999	12,347	37	—	646	858	9,516	59	571	661	—
Louisiana	1982	14,518	—	988	4,069	2,169	1,680	4,897	395	—	319
	1989	13,873	—	927	4,049	1,897	2,165	4,337	409	—	89
	1999	13,783	—	864	4,143	1,887	2,079	4,345	396	—	70
Mississippi	1982	16,685	—	1,034	4,210	3,434	4,310	3,391	131	—	175
	1989	16,987	—	854	3,939	3,470	5,508	3,040	134	—	42
	1999	18,588	—	866	4,885	3,218	5,834	3,561	151	—	73
North Carolina[b]	1982	19,545	151	532	6,046	2,484	7,034	2,171	425	214	488
	1989	18,450	223	571	5,446	2,252	6,844	2,244	385	158	328
	1999	18,710	246	411	5,538	2,568	6,975	2,453	172	194	153
Oklahoma	1982	4,316	—	—	814	704	2,369	331	93	—	6
	1989	4,741	—	—	956	747	2,600	360	78	—	—
	1999	4,895	—	—	1,099	702	2,591	410	94	—	—
South Carolina	1982	12,503	13	970	4,538	1,716	2,760	1,961	273	—	273
	1989	12,179	11	763	4,619	1,533	2,482	2,250	248	—	274
	1999	12,455	12	592	4,915	1,893	2,483	2,372	96	—	92
Tennessee	1982	12,959	50	—	1,303	1,422	9,259	757	32	137	—
	1989	13,265	64	—	1,334	1,592	9,477	639	43	111	6
	1999	13,965	104	—	1,365	1,625	9,911	609	241	16	94
Texas	1982	11,662	—	271	4,334	2,591	2,672	1,679	104	—	12
	1989	11,565	—	280	3,976	2,365	3,351	1,508	59	11	17
	1999	11,774	—	232	4,065	2,502	3,127	1,741	65	—	42
Virginia	1982	15,973	152	—	3,250	1,921	9,594	348	325	130	252
	1989	15,436	183	—	3,145	1,682	9,559	296	290	83	198
	1999	15,448	212	—	3,104	1,932	9,332	383	239	142	104
Total	1982	197,525	461	15,926	47,766	29,556	67,752	27,613	3,082	996	4,374
	1989	195,916	570	14,594	46,277	27,964	72,534	26,724	2,868	877	3,510
	1999	200,736	701	13,176	49,797	29,875	74,027	28,093	2,533	1,015	1,522

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA surveys conducted between 1972-82, 1982-89, and 1990-99, respectively. Kentucky data for 1999 are from the 1988 FIA survey, data for both the 1982 and 1989 reporting years are from the 1975 FIA survey of Kentucky.
[b] Estimates of white-red-jack pine in North Carolina include 7.9, 18.5, and 13.1 thousand acres of spruce-fir forest type for years 1982, 1989, and 1999, respectively.

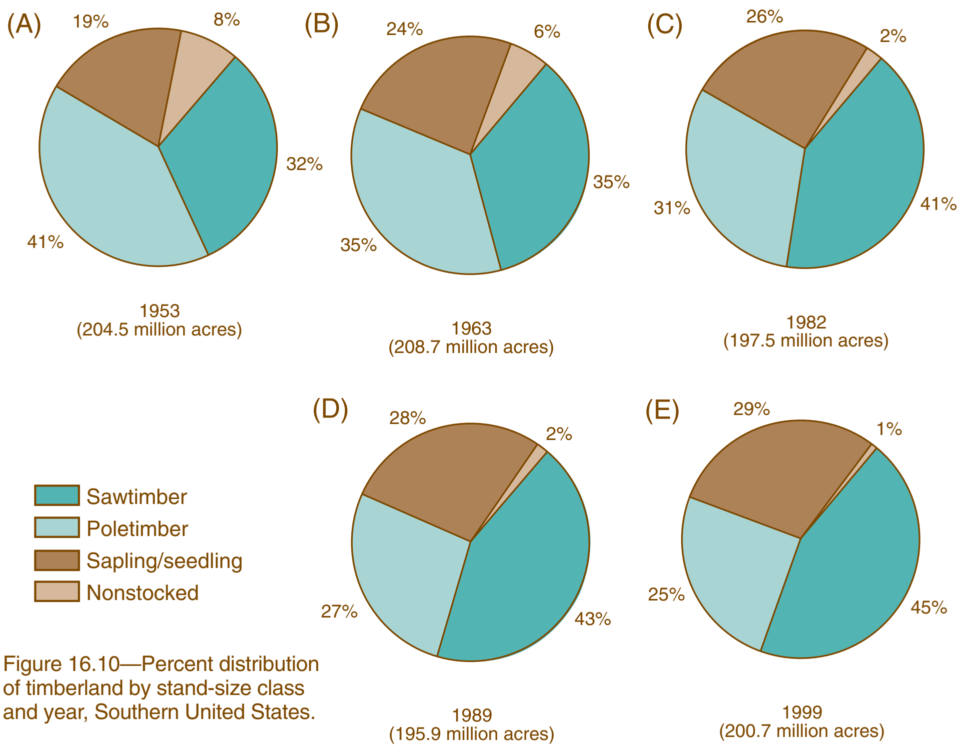

Figure 16.10—Percent distribution of timberland by stand-size class and year, Southern United States.

from 750,000 acres to 1 million acres between 1953 and 1999.

Lowland hardwoods, which in the past have accounted for as much as 19 percent of southern timberlands, occupied 15 percent of the area of timberland in 1999. Acres of oak-gum-cypress and elm-ash-cottonwood, which comprise the lowland hardwood group, declined from 39 million acres to 31 million acres over the past 46 years.

Distribution of timberland by stand size—The FIA classification of timberland acres by stand size gives an indication of the predominant size of the trees present. Each stand-size class—sawtimber, poletimber, and sapling-seedling—is defined by a specific range of diameters and by the trees comprising a plurality of live-tree stocking:

- *Sawtimber stands.* Stands at least 16.7 percent stocked with live trees, with half or more of total stocking in sawtimber and poletimber trees, and with sawtimber stocking at least equal to poletimber stocking. Sawtimber trees are softwood species at least 9.0 inches in diameter at breast height (d.b.h.) and hardwood species at least 11.0 inches d.b.h.
- *Poletimber stands.* Stands at least 16.7 percent stocked with live trees, of which half or more of total stocking is in poletimber and sawtimber trees, and with poletimber stocking exceeding that of sawtimber. Poletimber trees are live trees of any species at least 5.0 inches d.b.h. but smaller than sawtimber.
- *Sapling-seedling stands.* Stands at least 16.7 percent stocked with live trees of which more than half of total stocking is saplings and seedlings. Saplings are live trees 1.0 to 5.0 inches d.b.h., and seedlings are trees less than 1.0-inch d.b.h.

Timberland acres with less than 16.7 percent stocking are classed as nonstocked.

The distribution of timberland by stand size has changed considerably since 1953 (fig. 16.10). Acres of sawtimber and sapling-seedling stands have increased, while acres of poletimber stands and nonstocked acres decreased. Poletimber stands dominated in 1953, accounting for 41 percent of the acres of timberland (Smith and others 2001). Less than one-third of the stands were sawtimber, roughly one-fifth were classified as sapling-seedling stands, and 8 percent were nonstocked. A decade later, sawtimber and poletimber stands each occupied 35 percent of the South's timberland area. In 1963, stands with a plurality of stocking in saplings and seedlings accounted for nearly one-fourth of the area. These general trends continued; and by 1999, 45 percent of the timberland area was in sawtimber stands, one-quarter was in poletimber stands, and 29 percent was in sapling and seedling stands. Only 1 percent was nonstocked in 1999.

The trends in stand size differ for hardwoods and softwoods (table 16.7). Since 1982, the upward trend in the total area of sawtimber has been driven by increases in hardwood sawtimber. Hardwood sawtimber rose 17 percent to 65 million acres in 1999. Every State in the South, except South Carolina and Texas, had more hardwood sawtimber stands in 1999 than in 1982. Part of the reason for the increase is basic economics. Hardwood species are generally less desirable for timber products until they reach sawtimber size; and many hardwood stands are in remote mountainous areas, which are more difficult to log (chapter 13). As a result, more trees are left to grow into the larger diameter classes.

The area of softwood sawtimber has declined 8 percent since 1982. Florida, Georgia, Mississippi, and Texas have lost softwood sawtimber in successive inventories; and Alabama, Louisiana, and South Carolina have fewer acres in this class now than in 1982. The remaining five States have slightly more acres of sawtimber than a decade ago. The decline in sawtimber—softwood and hardwood—in South Carolina between 1989 and 1999 was due at least in part to damage from Hurricane Hugo in 1989.

Trends in Stand Origin: Planted Pines and Natural Stands

Timberland acres originate from natural regeneration or from planting or seeding by humans. Most hardwood stands have originated from natural reversion of nonforest land, or from natural regeneration after harvests of pine and hardwood sites. A large portion of the area of pine and oak-pine stands in 1999, however, originated by planting on nonforest acres, or by artificially regenerating sites following a final harvest. Pine plantations, all but unheard of 50 years ago, are now nearly as common as natural pine and oak-pine stands throughout much of the South's Piedmont and Coastal Plain regions (fig. 16.11). In fact, recent FIA inventories showed that planted pine

Table 16.7—Area of timberland by State, year, and stand-size class for softwood and hardwood, Southern United States

State	Year[a]	All classes	Sawtimber Softwood	Sawtimber Hardwood	Poletimber Softwood	Poletimber Hardwood	Sapling-seedling Softwood	Sapling-seedling Hardwood	Nonstocked
		Thousand acres							
Alabama	1982	21,358	2,930	3,945	2,706	4,514	2,376	4,774	114
	1989	21,659	2,985	4,593	2,042	4,334	2,201	5,409	95
	1999	21,932	2,587	5,053	2,139	3,773	2,722	5,615	44
Arkansas	1982	16,707	2,467	4,892	934	4,429	903	3,066	16
	1989	17,245	2,149	5,206	920	4,158	1,123	3,678	11
	1999	18,392	2,652	5,887	1,319	4,133	1,107	3,263	32
Florida	1982	15,664	1,946	3,020	2,409	1,711	2,832	1,735	2,011
	1989	14,983	1,833	3,094	2,330	1,553	2,909	1,492	1,772
	1999	14,651	1,655	3,132	2,437	1,587	3,083	2,330	428
Georgia	1982	23,734	4,444	5,065	3,769	3,953	3,020	2,790	694
	1989	23,631	3,946	5,340	3,038	3,257	3,934	3,455	663
	1999	23,796	3,569	6,044	3,253	2,390	3,818	4,333	390
Kentucky	1982	11,902	242	5,042	89	2,763	362	3,389	15
	1989	11,902	242	5,042	89	2,763	362	3,389	15
	1999	12,347	294	6,829	203	2,994	185	1,843	—
Louisiana	1982	14,518	2,719	5,144	1,322	2,108	1,016	1,889	319
	1989	13,873	2,881	5,172	961	1,557	1,134	2,079	89
	1999	13,783	2,681	5,468	957	1,205	1,370	2,034	70
Mississippi	1982	16,685	2,574	4,844	1,451	3,199	1,219	3,223	175
	1989	16,987	2,386	5,369	1,046	2,696	1,361	4,087	42
	1999	18,588	2,129	5,618	1,474	2,299	2,149	4,847	73
North Carolina	1982	19,545	2,268	5,944	2,181	4,111	2,280	2,273	488
	1989	18,450	2,576	6,403	2,049	3,238	1,615	2,242	328
	1999	18,710	2,586	6,531	2,061	2,878	1,548	2,953	153
Oklahoma	1982	4,316	349	868	245	1,274	221	1,354	6
	1989	4,741	392	905	221	1,422	343	1,458	—
	1999	4,895	392	1,105	530	1,474	176	1,218	—
South Carolina	1982	12,503	2,309	3,145	1,762	1,791	1,450	1,773	273
	1989	12,179	2,382	3,129	1,359	1,727	1,651	1,657	274
	1999	12,455	1,954	2,811	1,468	1,670	2,097	2,364	92
Tennessee	1982	12,960	439	4,884	519	4,510	394	2,213	—
	1989	13,265	596	5,926	471	3,926	331	2,010	6
	1999	13,965	622	6,569	359	3,099	488	2,734	94
Texas	1982	11,662	2,810	3,356	937	1,868	857	1,822	12
	1989	11,565	2,511	3,217	786	1,661	958	2,415	17
	1999	11,774	2,069	3,199	1,040	1,549	1,188	2,688	42
Virginia	1982	15,973	975	5,381	1,259	4,746	1,168	2,193	252
	1989	15,436	1,060	6,269	1,326	3,777	942	1,864	198
	1999	15,448	1,149	6,450	1,230	3,480	937	2,097	104
Total	1982	197,525	26,472	55,528	19,582	40,977	18,098	32,493	4,374
	1989	195,917	25,939	59,663	16,639	36,068	18,863	35,235	3,510
	1999	200,736	24,337	64,693	18,470	32,532	20,866	38,316	1,522

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA surveys conducted between 1972-82, 1982-89, and 1990-99, respectively. Kentucky data for 1999 are from the 1988 FIA survey, data for both the 1982 and 1989 reporting years are from the 1975 FIA survey of Kentucky.

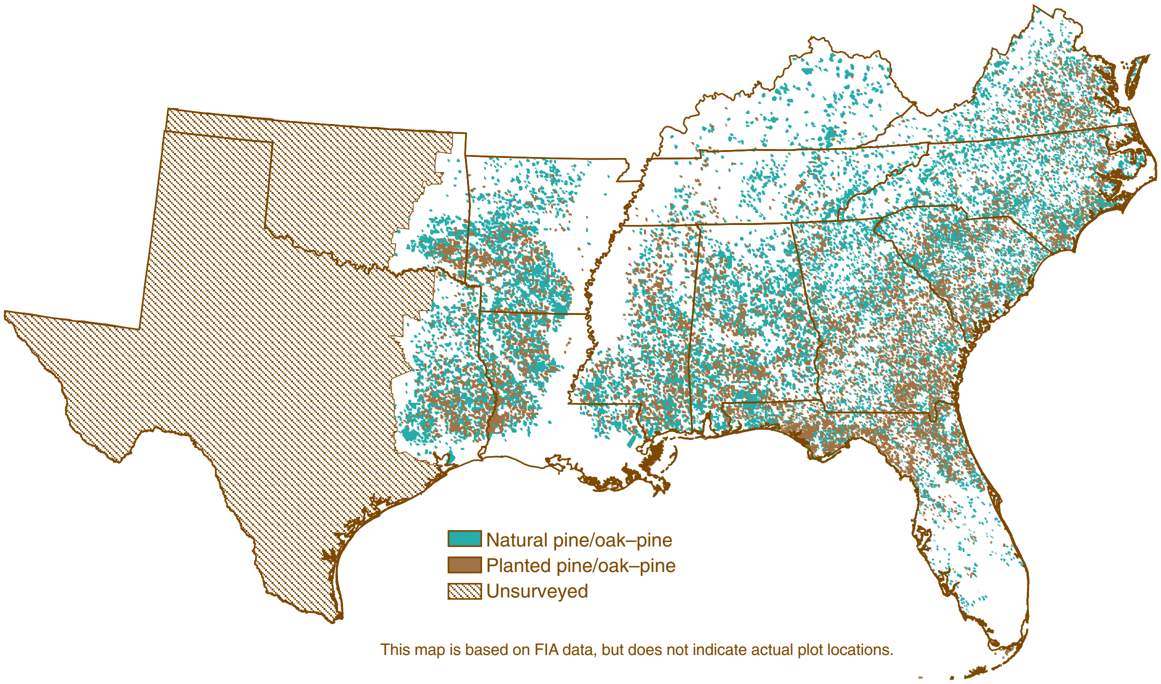

Figure 16.11—Distribution of pine and oak-pine timberland, by stand origin, Southern United States, 1999.

area exceeded natural pine in a few Southern States (table 16.8).

This increase in the area of planted pine and the impact—perceived or real—that this trend has had on current southern forests is arguably the most controversial issue in the South today. One means of tracking the shifts in natural and planted stands is to display the changes in timberland area by forest management types. FIA forest management types are classifications of timberland based on forest types and stand origin:

■ *Pine plantation.* Stands that have been artificially regenerated by planting or direct-seeding are classed as a pine or other softwood forest type and have at least 10 percent stocking.

■ *Natural pine.* Stands that have not been artificially regenerated are classed as a pine or other softwood forest type and have at least 10 percent stocking.

■ *Oak-pine.* Stands that have at least 10 percent stocking and are classed as a forest type of oak-pine. Hardwoods (usually upland oaks) constitute a plurality of the stand stocking, and pines account for 25 to 50 percent of stand stocking.

■ *Upland hardwood.* Stands that have at least 10 percent stocking and are classed as an oak-hickory or maple-beech-birch forest type.

■ *Lowland hardwood.* Stands that have at least 10 percent stocking and are classed as an oak-gum-cypress, elm-ash-cottonwood, palm, or other tropical forest type.

Regional trends in the distribution of timberland area by forest management type for all 13 Southern States are illustrated in figure 16.12. The data for years 1952, 1962, and 1970 are from "The South's Fourth Forest (U.S. Department of Agriculture Forest Service 1988) report. The 1982, 1989, and 1999 report years are based on FIA inventory data.

In 1952, the area of planted pine was less than 2 million acres, or 1 percent of the timberland area in the South (fig. 16.12). Natural pine stands, which stretched from coastal Virginia south to Louisiana, covered 72 million acres in 1952; and natural oak-pine stands occupied another 28 million acres. These natural pine and natural oak-pine stands created a mosaic of longleaf pine, shortleaf pine, slash pine, loblolly pine, Virginia pine, and other pine species in pure stands, or mixed with oak, gum, and other hardwoods. Over the next decade, planted pine acreage

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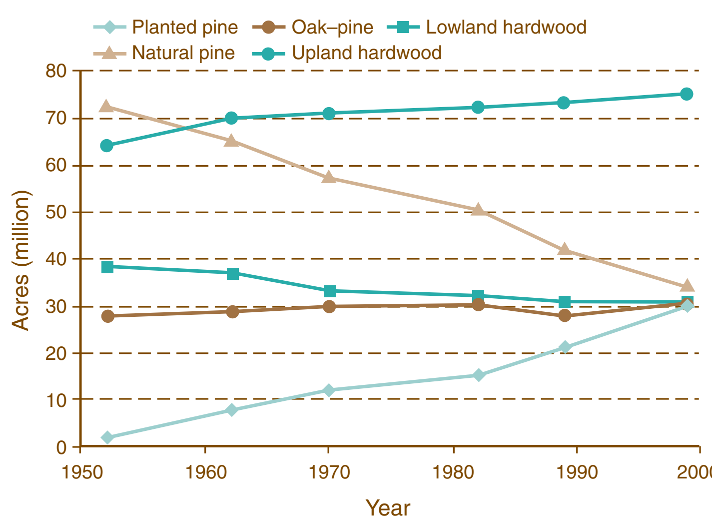

Figure 16.12—Trends in area of timberland by forest management type, Southern United States, 1952 to 1999.

Table 16.8—Area of timberland by State, forest management type, and year, Southern United States[a]

State and forest management type	1952[b]	1962[b]	1970[b]	1982[c]	1989[c]	1999[c]
	Thousand acres					
Alabama						
Planted pine	165	814	1,203	1,293	1,903	3,432
Natural pine	6,672	8,327	6,955	6,719	5,326	4,015
Oak-pine	5,803	4,839	4,982	5,081	4,426	4,522
Upland hardwood	5,622	5,397	5,773	5,650	7,415	7,650
Lowland hardwood	2,495	2,366	2,505	2,502	2,495	2,270
All types	20,757	21,743	21,418	21,244	21,565	21,889
Arkansas						
Planted pine	55	161	256	436	1,193	1,839
Natural pine	4,481	4,690	4,180	3,867	2,999	3,238
Oak-pine	2,181	2,667	2,870	2,995	3,039	3,137
Upland hardwood	8,500	8,351	7,779	6,568	7,269	7,127
Lowland hardwood	4,410	4,102	2,947	2,825	2,733	3,018
All types	19,627	19,971	18,032	16,692	17,233	18,359
Florida						
Planted pine	291	1,506	2,645	3,267	3,987	4,627
Natural pine	10,311	6,911	5,365	3,920	3,085	2,547
Oak-pine	751	1,137	1,558	1,320	1,116	1,463
Upland hardwood	2,452	2,565	2,423	1,240	1,114	1,981
Lowland hardwood	4,330	4,711	4,270	3,907	3,910	3,604
All types	18,135	16,830	16,261	13,654	13,212	14,222
Georgia						
Planted pine	357	1,592	2,738	3,583	5,031	6,070
Natural pine	13,260	11,620	9,855	7,650	5,886	4,570
Oak-pine	2,266	3,604	3,674	2,921	3,048	3,567
Upland hardwood	3,619	4,971	5,230	5,448	5,582	5,422
Lowland hardwood	4,467	4,511	3,605	3,438	3,422	3,777
All types	23,969	26,298	25,102	23,040	22,969	23,406
Louisiana						
Planted pine	103	893	1,274	1,406	1,471	2,169
Natural pine	4,625	4,575	4,022	3,651	3,505	2,837
Oak-pine	2,644	2,242	2,199	2,169	1,897	1,887
Upland hardwood	2,046	1,800	1,734	1,680	2,165	2,079
Lowland hardwood	6,621	6,526	5,901	5,292	4,747	4,741
All types	16,039	16,036	15,130	14,198	13,785	13,713
Mississippi						
Planted pine	284	645	933	1,138	1,544	2,964
Natural pine	5,147	5,133	5,166	4,106	3,248	2,788
Oak-pine	4,309	3,305	3,162	3,434	3,470	3,218
Upland hardwood	3,541	4,319	3,992	4,310	5,508	5,834
Lowland hardwood	3,572	3,642	3,522	3,522	3,174	3,711
All types	16,853	17,044	16,775	16,510	16,944	18,515
North Carolina						
Planted pine	96	359	762	1,004	1,614	2,093
Natural pine	8,607	7,962	7,084	5,724	4,626	4,103
Oak-pine	2,027	2,405	2,468	2,484	2,252	2,568
Upland hardwood	5,653	6,248	7,010	7,249	7,001	7,169
Lowland hardwood	3,199	3,015	2,806	2,595	2,629	2,624
All types	19,582	19,989	20,130	19,056	18,122	18,557

(continued)

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Table 16.8—Area of timberland by State, forest management type, and year, Southern United States[a] (continued)

State and forest management type	1952[b]	1962[b]	1970[b]	1982[c]	1989[c]	1999[c]
	Thousand acres					
Oklahoma						
Planted pine	6	33	50	49	250	474
Natural pine	728	732	751	766	706	624
Oak-pine	607	637	672	704	747	702
Upland hardwood	3,406	3,063	2,696	2,369	2,600	2,591
Lowland hardwood	328	427	451	424	439	504
All types	5,075	4,892	4,620	4,312	4,741	4,895
South Carolina						
Planted pine	233	759	1,077	1,354	2,004	2,672
Natural pine	5,888	4,781	4,430	4,168	3,388	2,847
Oak-pine	834	1,454	1,794	1,716	1,533	1,893
Upland hardwood	1,769	2,456	2,879	2,760	2,482	2,483
Lowland hardwood	3,160	2,721	2,265	2,233	2,498	2,468
All types	11,884	12,171	12,445	12,231	11,905	12,363
Tennessee						
Planted pine	106	297	317	317	357	458
Natural pine	1,693	1,164	1,019	1,035	1,041	1,011
Oak-pine	2,191	1,328	1,595	1,422	1,592	1,625
Upland hardwood	7,610	9,536	9,192	9,396	9,588	9,927
Lowland hardwood	951	1,040	698	790	682	850
All types	12,551	13,365	12,821	12,959	13,260	13,871
Texas						
Planted pine	104	293	457	558	1,191	1,767
Natural pine	5,643	5,165	4,583	4,047	3,064	2,530
Oak-pine	2,178	2,314	2,458	2,591	2,365	2,502
Upland hardwood	2,886	2,855	2,954	2,672	3,362	3,127
Lowland hardwood	2,270	2,333	2,267	1,782	1,566	1,806
All types	13,081	12,960	12,719	11,650	11,548	11,732
Virginia						
Planted pine	46	235	432	680	1,170	1,468
Natural pine	4,932	3,848	3,282	2,722	2,158	1,848
Oak-pine	1,297	1,569	1,753	1,921	1,682	1,932
Upland hardwood	8,278	9,541	9,897	9,724	9,642	9,473
Lowland hardwood	944	559	495	673	586	622
All types	15,497	15,752	15,859	15,720	15,238	15,343
Total						
Planted pine	1,846	7,587	12,144	15,085	21,715	30,033
Natural pine	71,987	64,908	56,692	48,375	39,032	32,958
Oak-pine	27,088	27,501	29,185	28,757	27,167	29,016
Upland hardwood	55,382	61,102	61,559	59,066	63,728	64,863
Lowland hardwood	36,747	35,953	31,732	29,983	28,881	29,995
All types[d]	193,050	197,051	191,312	181,265	180,522	186,865

Numbers in columns may not sum to totals due to rounding.
[a] Excludes Kentucky.
[b] Data for 1952, 1962, and 1970 are from "The South's Fourth Forest" (U.S. Department of Agriculture, Forest Service 1988).
[c] Data for 1982, 1989, and 1999 are based on FIA surveys conducted between 1972-82, 1982-89, and 1990-99, respectively.
[d] Does not include nonstocked acres.

reached 8 million acres as natural stands were harvested and regenerated and as pine species were planted on idle cropland and other nonforest acres.

The Soil Bank Program of the late 1950s essentially marked the beginning of extensive pine plantations in the South (Frederick and Sedjo 1991). This Federal program provided incentives to landowners to "withdraw land from agriculture and put it into uses such as forestry." By 1962, planted pine stands accounted for 4 percent of the total timberland area and 11 percent of the area of pine. Natural pine area declined to 65 million acres by 1962, and oak-pine increased to 29 million acres. This pattern of increasing area of planted pine and decreasing area of natural pine stands has continued over the past few decades. The rate of pine planting accelerated after the mid-1980s, helped along by Federal efforts such as the Conservation Reserve Program, which offered incentives to farmers and ranchers to "convert highly erodible agriculture lands into forest" (Frederick and Sedjo 1991). In 1999, planted pine stands occupied 30 million acres, or 15 percent of the South's timberland area, and 47 percent of the area of pine in the region. Natural pine stands occupied 34 million acres in 1999.

Figure 16.13 and table 16.8 show the trends since 1952 in area of timberland by forest management type and State. The figure and table include all forest management types, but the primary focus of this discussion is on the changes in the area of natural and planted pine.

Florida and Georgia typify how the pine resource has changed throughout much of the South. In 1952, natural pine stands occupied 13 million acres in Georgia; and planted pine stands totaled 357,000 acres. Florida's 10 million acres of natural pine was 57 percent of its timber base in 1952. The area of planted pine in Florida was just 291,000 acres at that time. Together, these two States accounted for 24 million acres, or one-third of the natural pine resource in 12 Southern States in 1952. In 1999, the combined acreage of natural pine in both States amounted to 7 million acres. Acres of planted pine outnumbered those of natural pine in both States, and in Mississippi, as well. Natural and planted pine acreages were nearly equal in Louisiana and Virginia in 1999.

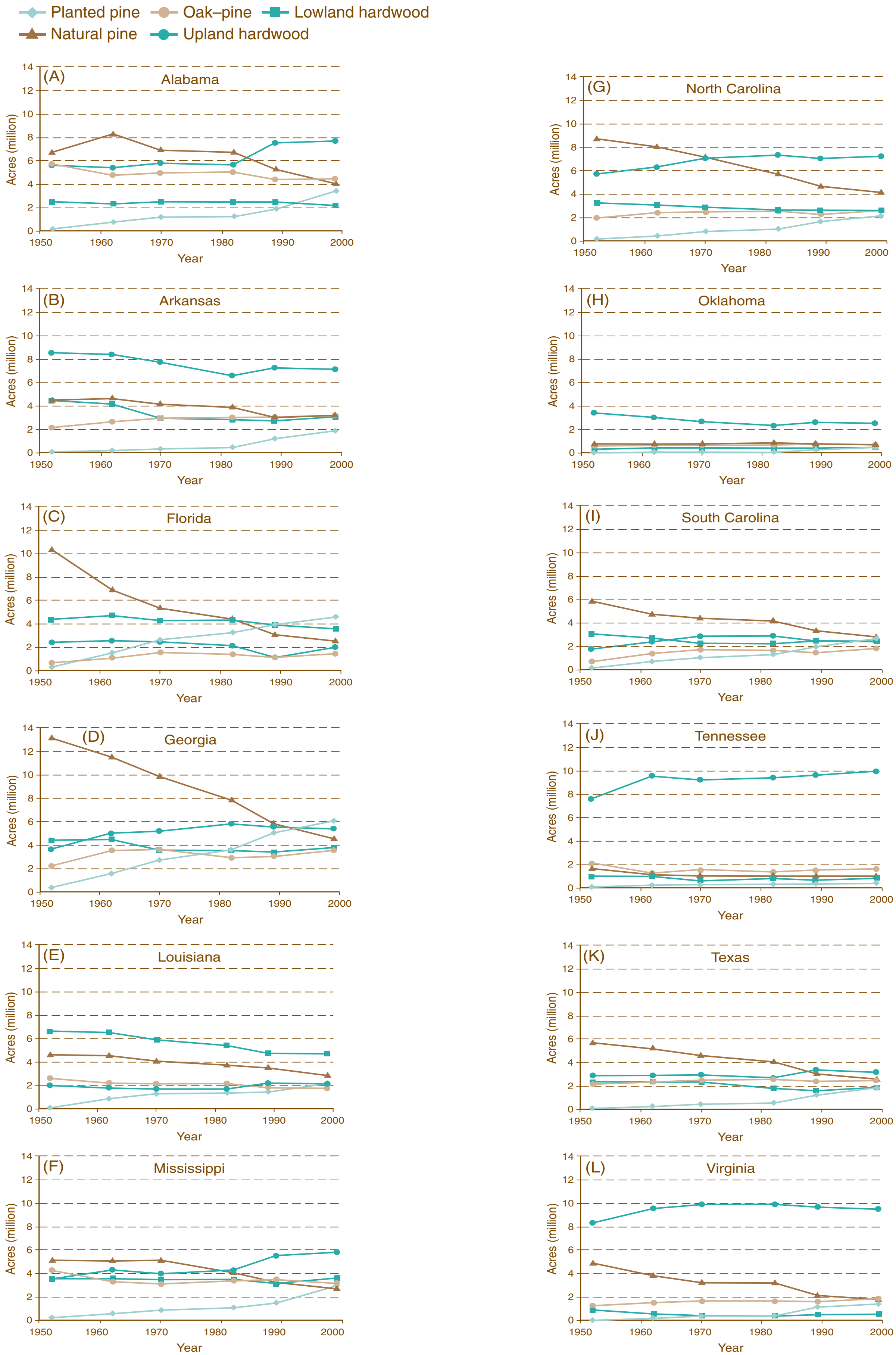

Figure 16.13—Trends in timberland area by State, year, and forest management type, Southern United States (excludes Kentucky).

Planted pine may surpass natural pine in these States in the near future, as was recently witnessed in Alabama (Hartsell and Brown 2002) and South Carolina (Conner and Sheffield 2001b). The just-released inventory results revealed that pine plantation acreage has now surpassed the area of natural pine by 1.1 million acres in Alabama and by 130,000 acres in South Carolina. The same trend may be occurring in North Carolina, as latest inventory statistics for that State's southern Coastal Plain showed there are now 1 million acres of pine plantation and 900,000 acres of natural pine (Conner and Sheffield 2002b). Whether this trend holds for the other pine-dominated regions in that State remains to be seen.

Pine plantation acreage is undoubtedly on the rise throughout the South. However, the perception by some that planted pine acreage has increased solely at the displacement of natural pine and other forest types is not entirely correct. Many hardwood and natural pine stands, indeed, have been harvested and then planted or seeded with pine. However, as previously discussed, much of the decline in natural pine and hardwood stands was due to diversions to agriculture and urban land uses. In addition, changes in the distribution of timberland area result from shifts of acres among forest management types, including shifts between planted and natural stand origin.

Shifts in acreage of planted and natural stands: reclassifying forest management types—Natural succession and disturbance, artificial regeneration, and timber harvesting alter species distributions and stocking levels. A change in forest management type often results. For example, when oak or other hardwoods become established in a natural pine stand, the management type classifications can change from natural pine to oak-pine and eventually to upland hardwoods. Or a planted pine stand, after a final harvest or following some intermediate treatment, can become stocked with enough hardwood stems to change its management type to planted oak-pine. Moreover, even if no harvesting or management activity occurs, a planted stand may, through natural succession, become indistinguishable from a natural stand and

Table 16.9—Change in area of timberland between 1989 and 1999 by State, previous and current forest management type, Southern United States[a]

	Current forest management type[b]						
State and previous forest management type	Planted pine-oak pine	Natural pine	Natural oak-pine	Upland hard-wood	Lowland hard-wood	Non-stocked	Non-forest
	Thousand acres						
Alabama							
Planted pine/ oak-pine	1,977	137	51	160	—	5	33
Natural pine	473	2,832	1,023	801	45	11	146
Natural oak-pine	265	604	1,592	1,157	28	—	116
Upland hardwood	621	207	1,011	5,116	115	6	196
Lowland hardwood	47	6	104	172	2,026	—	68
Nonstocked	12	5	—	—	6	5	—
Nonforest	644	224	134	245	50	16	—
All types	4,039	4,015	3,915	7,649	2,270	44	—
Arkansas							
Planted pine/ oak-pine	1,393	131	31	52	6	—	6
Natural pine	182	2,268	377	234	6	—	92
Natural oak-pine	86	628	1,595	422	6	—	62
Upland hardwood	350	109	556	5,979	179	7	309
Lowland hardwood	19	—	36	41	2,620	14	71
Nonstocked	6	—	—	—	—	—	—
Nonforest	174	102	173	400	201	12	—
All types	2,210	3,238	2,767	7,127	3,018	32	—
Florida							
Planted pine/ oak-pine	3,714	132	38	147	32	—	54
Natural pine	433	2,349	293	136	67	—	172
Natural oak-pine	61	199	522	117	104	—	63
Upland hardwood	252	10	174	1,474	12	—	149
Lowland hardwood	136	34	171	87	3,481	—	135
Nonstocked	—	—	—	—	—	—	—
Nonforest	299	80	20	53	25	—	—
All types	4,895	2,804	1,218	2,013	3,720	—	—
Georgia							
Planted pine/ oak-pine	4,669	165	72	125	59	—	61
Natural pine	617	3,785	811	471	158	—	330
Natural oak-pine	114	404	1,405	436	159	—	106
Upland hardwood	503	97	582	4,343	108	—	267
Lowland hardwood	129	30	236	65	3,354	—	72
Nonstocked	—	—	—	—	—	—	—
Nonforest	528	219	54	63	37	—	—
All types	6,560	4,700	3,159	5,503	3,875	—	—
Louisiana							
Planted pine/ oak-pine	1,446	88	29	82	—	11	19
Natural pine	362	2,104	487	402	6	16	90
Natural oak-pine	154	434	605	335	85	5	22
Upland hardwood	363	135	363	857	353	—	78
Lowland hardwood	28	—	67	310	3,985	5	143
Nonstocked	5	—	—	—	6	11	7
Nonforest	119	76	27	93	306	22	—
All types	2,478	2,838	1,578	2,079	4,741	70	—

continued

Table 16.9—Change in area of timberland between 1989 and 1999 by State, previous and current forest management type, Southern United States[a] (continued)

	Current forest management type[b]						
State and previous forest management type	Planted pine-oak pine	Natural pine	Natural oak-pine	Upland hardwood	Lowland hardwood	Non-stocked	Non-forest
	Thousand acres						
Mississippi							
Planted pine/ oak-pine	1,897	104	69	186	5	13	37
Natural pine	299	1,902	455	504	22	—	82
Natural oak-pine	114	420	1,261	766	106	—	48
Upland hardwood	604	123	546	3,888	277	6	136
Lowland hardwood	18	—	70	92	3,031	13	36
Nonstocked	7	—	—	—	—	—	—
Nonforest	705	240	136	398	270	42	—
All types	3,645	2,788	2,537	5,834	3,711	73	—
North Carolina							
Planted pine/ oak-pine	1,600	17	9	29	2	—	20
Natural pine	252	3,583	513	218	96	—	170
Natural oak-pine	48	383	1,346	320	96	—	45
Upland hardwood	170	69	421	6,327	145	—	177
Lowland hardwood	99	10	86	258	2,312	—	59
Nonstocked	—	—	—	—	—	—	—
Nonforest	87	101	48	49	15	—	—
All types	2,257	4,163	2,422	7,202	2,666	—	—
Oklahoma							
Planted pine/ oak-pine	423	6	—	6	—	—	—
Natural pine	39	512	105	36	—	—	11
Natural oak-pine	—	94	386	66	—	—	6
Upland hardwood	103	6	102	2,218	34	—	50
Lowland hardwood	6	—	—	33	396	—	—
Nonstocked	—	—	—	—	—	—	—
Nonforest	—	6	12	232	74	—	—
All types	571	624	605	2,591	504	—	—
South Carolina							
Planted pine/ oak-pine	1,913	80	54	60	21	—	24
Natural pine	245	2,367	444	181	103	—	93
Natural oak-pine	76	269	770	200	99	—	36
Upland hardwood	176	24	304	1,960	95	—	118
Lowland hardwood	117	23	143	71	2,151	—	48
Nonstocked	—	—	—	—	—	—	—
Nonforest	286	126	47	30	21	—	—
All types	2,812	2,890	1,762	2,502	2,489	—	—
Tennessee							
Planted pine/ oak-pine	391	5	14	20	—	2	3
Natural pine	30	886	83	62	5	5	51
Natural oak-pine	26	28	1,250	166	3	3	81
Upland hardwood	57	9	71	9,193	28	39	360
Lowland hardwood	6	—	4	39	691	8	31
Nonstocked	—	—	—	—	—	6	—
Nonforest	43	82	110	448	123	32	—
All types	552	1,011	1,531	9,927	850	94	—

continued

Table 16.9—Change in area of timberland between 1989 and 1999 by State, previous and current forest management type, Southern United States[a] (continued)

State and previous forest management type	Current forest management type[b]						
	Planted pine-oak pine	Natural pine	Natural oak-pine	Upland hard-wood	Lowland hard-wood	Non-stocked	Non-forest
	Thousand acres						
Texas							
Planted pine/oak-pine	1,254	87	42	81	6	7	33
Natural pine	288	1,936	421	257	17	—	75
Natural oak-pine	169	299	1,000	424	42	—	39
Upland hardwood	405	98	408	1,940	237	6	202
Lowland hardwood	22	6	52	40	1,341	—	171
Nonstocked	—	—	—	—	—	—	—
Nonforest	118	106	92	386	163	29	—
All types	2,254	2,530	2,015	3,127	1,806	42	—
Virginia							
Planted pine/oak-pine	1,275	18	—	55	—	—	11
Natural pine	115	1,617	227	134	4	—	83
Natural oak-pine	41	171	923	302	5	—	38
Upland hardwood	277	20	459	8,881	88	—	170
Lowland hardwood	8	3	3	73	524	—	31
Nonstocked	—	—	—	—	—	—	—
Nonforest	43	51	43	74	14	—	—
All types	1,758	1,880	1,656	9,518	635	—	—
Total							
Planted pine/oak-pine	21,951	970	408	1,001	131	37	300
Natural pine	3,335	26,140	5,238	3,437	528	32	1,394
Natural oak-pine	1,154	3,933	12,653	4,710	732	8	660
Upland hardwood	3,881	908	4,997	52,176	1,671	63	2,210
Lowland hardwood	634	112	973	1,281	25,913	40	864
Nonstocked	30	5	—	—	11	22	7
Nonforest	3,046	1,412	895	2,470	1,299	153	—
All types	34,031	33,479	25,163	65,074	30,285	355	—

Numbers in columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1990 and 1999.

would be classified as natural pine, oak-pine, or hardwood.

Table 16.9 displays the changes in forest management types that occurred between 1989 and 1999. The columns of the table give the most recent (1999) estimate of acres in each management type. The extreme left column lists the previous management type that identifies how these acres were classified in the previous (1989) inventory. Data for Kentucky were not available.

Using the management type totals for 12 of the region's 13 States, planted pine and planted oak-pine combined totaled 34 million acres in 1999. Most of that acreage—about 22 million acres—was classified as planted pine/oak-pine in the previous survey. Planted pine/oak-pine acreage increased 12 million acres between surveys. What was the source for the increase in acres of planted stands? More than 3 million of the additional acres classified as planted pine/oak-pine in 1999 were natural pine stands in 1989. Another 1 million acres of natural oak-pine were reclassified as planted stands, as were nearly 5 million acres of upland and lowland hardwoods combined. The change in management type classification for these acres likely occurred as the result of harvesting followed by artificial regeneration.

Acres previously classified as nonforest were sources for "new" planted stands. Between 1989 and 1999, over 3 million acres of nonforest land were regenerated and reclassified as planted pine/oak-pine stands. It is these acres that account for much of the increase in timberland area since 1989. The greatest loss of timberland to nonforest occurred in upland hardwood forest types, which lost over 2 million acres since 1989.

Many timberland acres with a planted forest management type also were reclassified. In all, about 3 million acres identified as planted pine/oak-pine in 1989 were reclassified as natural stands by 1999. This change in type included 1 million acres reclassified as upland hardwoods, 970,000 acres reclassified as natural pine, and 408,000 acres reclassified as natural oak-pine.

Stand-age structure: young pine plantations and older natural stands—The importance of stand age has increased as planted stands have accounted for an increasing percentage of the South's timberland area. Part of the argument against pine plantations is that the intensively managed, comparatively young planted pine stands lack the biological diversity of natural stands. This shortcoming makes plantations less desirable for wildlife habitat, recreation, and other forest-derived amenities.

As a general rule, management of pine plantations dictates that few stands ever reach 50 years of age. Of the 34 million acres of planted pine/oak-pine stands in 1999, over half were less than 13 years old, and 81 percent were less than 23 years old (fig. 16.14 and table 16.10). Planted stands reaching 50 years or older are often being managed for sawtimber, or are possibly no longer being managed at all, and were left to return to a natural condition.

Natural stands tend to encompass a wider range of stand ages, but few 100 year-old natural stands still exist in the South. In 1999, only 3 million acres of southern timberland supported stands older than 93 years, and 88 percent of those stands were hardwoods (table 16.10).

The age distribution for hardwoods showed that most stands were between 33 and 62 years old (fig. 16.14). Thirty-four percent of hardwood stands were younger than 33 years, and less than one-quarter were older than 62 years.

Natural pine/oak-pine acres were skewed toward comparatively young age classes—53 percent of the stands were less than 33 years old.

Trends in Growing-Stock Volume

Historically, FIA has reported tree volumes based on the growing-stock classification. The definition of growing stock is a live tree of a commercial species that possesses, or has the potential, to produce a 12-foot sawlog. The log(s) must meet dimension and merchantability standards and have at least one-half of the gross board-foot volume in sound wood. This definition was modified in 1988. The new definition states that trees should have one-third of the gross board-foot volume in sound wood. Except for this and a few other changes, the definition of growing stock has remained constant and provides a steady benchmark to investigate trends in tree volume. The FIA data used in this report do not include volumes of trees less than

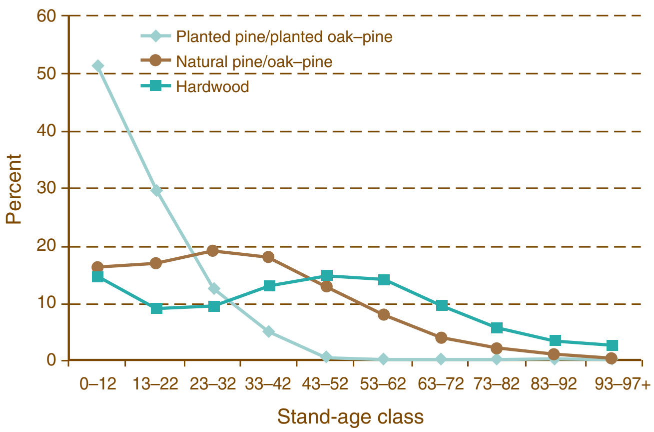

Figure 16.14—Percent distribution of timberland area within forest management types, by stand-age class, Southern United States, 1999.

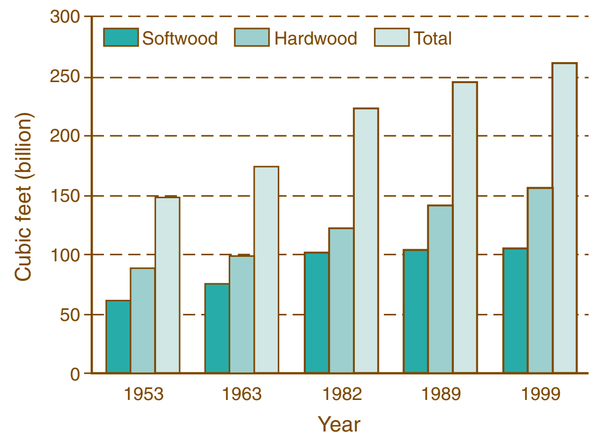

Figure 16.15—Volume of growing stock on timberland by species group and year, Southern United States.

Table 16.10—Area of timberland by stand-age class and forest management type, Southern United States[a], 1999

Stand-age class	All types	Forest management type[b]						
		Pine planted	Oak-pine planted	Natural pine	Natural oak-pine	Upland hardwood	Lowland hardwood	Non-stocked
	Thousand acres							
0–7	25,715	8,495	1,607	3,019	2,624	7,327	2,384	259
8–12	16,137	6,500	829	2,199	1,801	3,529	1,228	51
13–17	14,911	5,492	559	2,583	1,908	3,369	992	8
18–22	13,987	3,813	266	3,257	2,172	3,441	1,023	15
23–27	12,842	2,413	253	3,419	2,273	3,366	1,111	6
28–32	12,270	1,476	189	3,356	2,323	3,672	1,252	3
33–37	12,605	1,034	120	3,297	2,236	4,137	1,781	0
38–42	12,655	506	72	3,056	2,053	4,791	2,177	0
43–47	11,483	132	25	2,465	1,821	4,740	2,300	—
48–52	10,876	101	13	1,857	1,533	4,926	2,444	2
53–57	9,753	80	7	1,616	1,198	4,253	2,598	—
58–62	8,823	17	—	1,059	889	4,292	2,564	2
63–67	6,966	24	—	762	706	3,255	2,217	3
68–72	5,198	—	—	599	388	2,733	1,476	2
73–77	4,097	3	—	358	419	2,001	1,315	2
78–82	2,836	—	—	218	246	1,425	944	2
83–87	2,259	—	6	124	205	1,137	788	—
88–92	1,833	—	—	91	146	882	713	—
93–97+	3,144	—	—	143	224	1,798	980	—
All classes[a]	188,388	30,086	3,945	33,479	25,164	65,075	30,285	355

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell; 0 indicates a value of >0 but <.5 for the cell.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1990 and 1999.

Table 16.11—Volume of growing stock on timberland by State and year, Southern United States

State	1953	1963	1982	1989	1999
	Year[a]				
	Million cubic feet				
Alabama	12,352	16,466	19,350	21,394	23,076
Arkansas	14,109	15,069	17,369	18,999	21,687
Florida	8,901	10,686	13,815	14,422	15,366
Georgia	19,351	22,701	31,268	31,078	31,704
Kentucky	6,351	8,924	11,968	14,610	16,002
Louisiana	11,009	14,668	16,674	19,249	18,844
Mississippi	10,044	11,541	17,426	20,202	20,611
North Carolina	21,420	23,160	28,307	31,387	32,742
Oklahoma	1,381	1,519	2,052	2,314	3,001
South Carolina	10,212	12,268	17,706	18,009	16,685
Tennessee	8,250	9,298	12,935	16,646	22,456
Texas	7,893	9,415	12,238	12,713	12,939
Virginia	17,197	18,357	22,804	24,965	26,487
Total	148,470	174,072	223,913	245,987	261,601

Numbers in columns may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

Table 16.12—Volume of softwood growing stock on timberland by State and year, Southern United States

State	1953	1963	1982	1989	1999
	Year[a]				
	Million cubic feet				
Alabama	5,875	8,684	10,705	11,423	11,102
Arkansas	4,640	5,812	8,244	7,918	9,342
Florida	5,384	6,685	8,940	9,006	9,425
Georgia	10,751	12,513	16,682	15,713	15,224
Kentucky	493	567	916	1,110	1,218
Louisiana	4,253	6,357	9,030	10,842	9,928
Mississippi	3,674	5,259	9,013	9,298	9,208
North Carolina	9,097	9,634	11,305	12,041	12,530
Oklahoma	541	692	1,008	1,037	1,395
South Carolina	4,800	6,066	9,178	8,944	8,034
Tennessee	1,227	1,480	2,434	2,893	3,586
Texas	4,211	6,062	8,117	7,900	7,879
Virginia	5,516	5,276	5,929	6,258	6,648
Total	60,462	75,087	101,501	104,383	105,518

Numbers in columns may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

5.0 inches d.b.h. All volume data are derived from the 2001 RPA report and include the State of Kentucky, except any analysis performed using forest type. Volume by forest type was investigated using FIA data that excluded Kentucky so that the impacts of pine plantations could be reported.

Volume has increased between survey periods for both hardwood and softwood growing stock. This increase has been fairly steady, except for a slight leveling off after 1982. Between 1953 and 1999, total volume increased from 148,470 million cubic feet to 261,601 million cubic feet (table 16.11). The volume of softwood growing stock increased from 60,462 million cubic feet to 105,518 million cubic feet (table 16.12), and hardwood volume increased from 88,008 to 156,085 million cubic feet (fig. 16.15, table 16.13). The majority of this change took place between 1953 and 1982. This period accounted for 67 percent of the total increase in growing-stock volume, 91 percent of the increase in softwood volume, and 51 percent of the increase in hardwood volume.

State and Federal reforestation programs stimulated the increase in volume after World War II. Volume increases in the late 1960s to mid-1970s are a direct result of the maturing of trees planted by these reforestation projects. Data from the *South's Fourth Forest* (1988) indicate a huge increase in the number of acres reforested in the mid-1950s to early 1960s, with a peak of 1.7 million acres in 1959. The increase in growing stock in tables 16.11, 16.12, and 16.13 is a direct result of this reforestation effort.

Changes in volume by diameter class—Changes in total growing-stock volume by 2-inch diameter class are displayed in figure 16.16. Note that the second to last diameter class encompasses all trees 21.0 to 28.9 inches d.b.h. This broad class explains the large bump at the end of each year's curve. The increase in volume from 1953 to 1982 was particularly high for trees less than 14.0 inches d.b.h. This situation is attributable to the fact that trees are not included in estimates of growing-stock volume until they reach 5.0 inches d.b.h. At that time, their volume is added to the inventory and is called "ingrowth." Since 1982, the volume in the 9.0- to 10.9-inch diameter class has never varied by

Table 16.13—Volume of hardwood growing stock on timberland by State and year, Southern United States

State	Year[a] 1953	1963	1982	1989	1999
	Million cubic feet				
Alabama	6,477	7,782	8,646	9,971	11,974
Arkansas	9,469	9,257	9,125	11,081	12,345
Florida	3,517	4,001	4,874	5,416	5,942
Georgia	8,600	10,188	14,586	15,365	16,480
Kentucky	5,858	8,357	11,052	13,500	14,785
Louisiana	6,756	8,311	7,644	8,408	8,916
Mississippi	6,370	6,282	8,413	10,904	11,403
North Carolina	12,323	13,526	17,002	19,345	20,214
Oklahoma	840	827	1,044	1,277	1,607
South Carolina	5,412	6,202	8,528	9,065	8,651
Tennessee	7,023	7,818	10,501	13,753	18,870
Texas	3,682	3,353	4,122	4,813	5,060
Virginia	11,681	13,081	16,875	18,707	19,839
Total	88,008	98,985	122,412	141,604	156,085

Numbers in columns may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

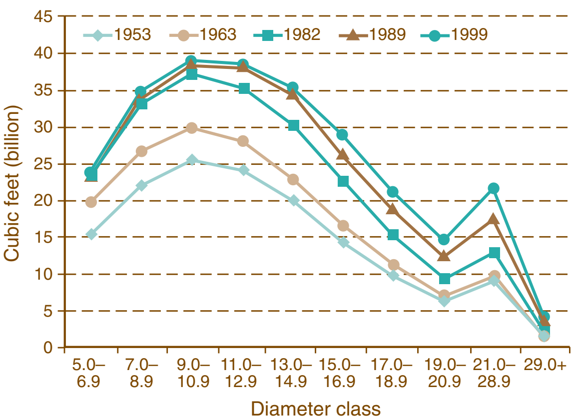

Figure 16.16—Volume of growing stock on timberland by diameter class and year, Southern United States.

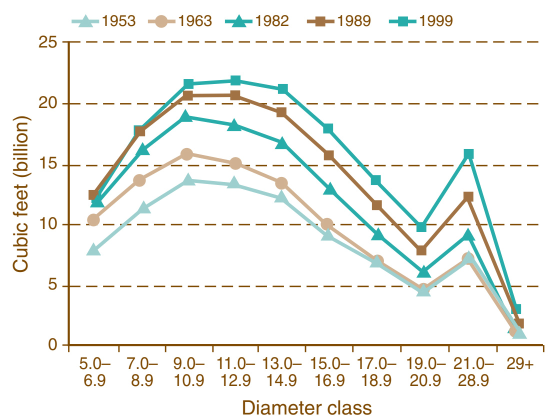

Figure 16.18—Volume of hardwood growing stock on timberland by diameter class and year, Southern United States.

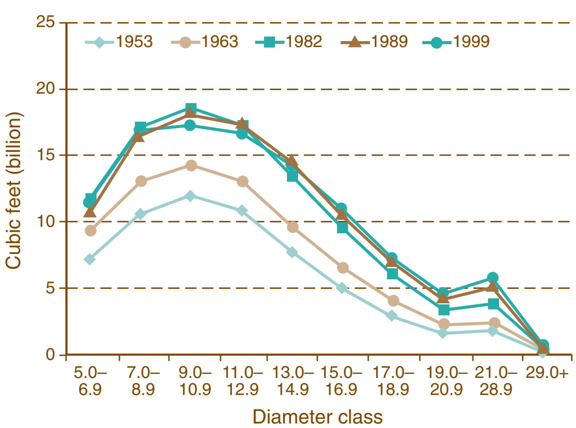

Figure 16.17—Volume of softwood growing stock on timberland by diameter class and year, Southern United States.

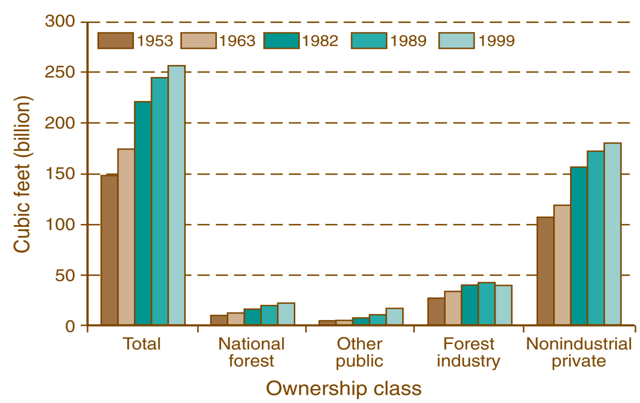

Figure 16.19—Volume of growing stock on timberland by ownership class and year, Southern United States.

Table 16.14—Volume of growing stock on timberland by year and diameter class, Southern United States

		Diameter class (*inches at breast height*)									
Year[a]	All classes	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–28.9	29+
	Million cubic feet										
1953	148,470	15,230	21,998	25,726	24,255	19,942	14,316	9,955	6,271	9,221	1,556
1963	174,072	19,733	26,809	30,026	28,160	23,055	16,602	11,232	7,119	9,767	1,568
1982	223,913	23,659	33,374	37,434	35,616	30,392	22,783	15,572	9,640	13,201	2,242
1989	245,987	23,295	34,194	38,588	38,005	33,919	26,318	18,763	12,295	17,493	3,117
1999	261,604	23,667	34,724	38,875	38,342	35,402	29,027	21,216	14,635	21,646	4,071

Numbers in rows may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

Table 16.15—Volume of softwood growing stock on timberland by year and diameter class, Southern United States

		Diameter class (*inches at breast height*)									
Year[a]	All classes	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–28.9	29+
	Million cubic feet										
1953	60,462	7,143	10,610	12,027	10,912	7,738	5,106	3,109	1,691	1,879	247
1963	75,087	9,339	13,074	14,241	13,050	9,653	6,625	4,108	2,354	2,399	243
1982	101,501	11,565	17,005	18,565	17,271	13,599	9,555	6,089	3,507	3,924	419
1989	104,383	10,686	16,464	18,023	17,269	14,509	10,456	6,991	4,280	5,109	597
1999	105,518	11,347	16,873	17,236	16,523	14,199	10,960	7,285	4,634	5,753	708

Numbers in rows may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

HEALTH

Table 16.16—Volume of hardwood growing stock on timberland by year and diameter class, Southern United States

		Diameter class (*inches at breast height*)									
Year[a]	All classes	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–28.9	29+
	Million cubic feet										
1953	88,008	8,087	11,388	13,699	13,343	12,204	9,210	6,846	4,580	7,342	1,309
1963	98,985	10,394	13,735	15,785	15,110	13,402	9,977	7,124	4,765	7,368	1,325
1982	122,413	12,093	16,369	18,870	18,345	16,793	13,228	9,483	6,132	9,277	1,824
1989	141,604	12,609	17,731	20,565	20,736	19,410	15,862	11,772	8,015	12,384	2,520
1999	156,086	12,320	17,851	21,639	21,819	21,203	18,067	13,931	10,001	15,892	3,363

Numbers in rows may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

more than 3 percent (table 16.14). The volume of growing-stock trees for diameter classes greater than 10.9 inches has increased steadily in successive survey periods.

For softwood growing stock, volume in all years peaks in the 9.0- to 10.9-inch diameter class (fig. 16.17). This peak was greatest in 1982, as recent surveys show a slight decrease in volume for this tree size. All years have increases in volume for each diameter class greater that 13.0 inches d.b.h. (table 16.15). For hardwood growing stock, volume peaks in the 10-inch diameter class (fig. 16.18, table 16.16). The general shape of the hardwood distribution curve is more rounded, with very large volumes in the 9.0- to 10.9-, 11.0- to 12.9- and 13.0- to 14.9-inch diameter classes.

Conversely, softwood growing-stock volume is concentrated in the smaller diameter classes.

Volume of growing stock by ownership—Because NIPF landowners hold the lion's share of the South's timberland, it follows that the majority of the volume occurs on their land (fig. 16.19). NIPF landowners have always accounted for 69 to 72 percent of the total growing-stock volume in the South (table 16.17). The growing-stock volume for all ownerships has increased in each survey period. The increases in growing-stock volume brought about by the reforestation efforts of the 1930s, 1950s, and early 1960s are clearly seen in figure 16.19, particularly for NIPF land.

In 1953, NIPF landowners controlled 71 percent of the growing-stock volume. Since then, the proportion controlled by NIPF owners has declined due to major increases for other types of owners. Growing-stock volume on forest industry land increased 50 percent from 1953 to 1999. The volume on national forests increased 113 percent and that on other public land increased 251 percent.

Table 16.17—Volume of growing stock on timberland by year and ownership class, Southern United States

		Ownership class			
Year[a]	All classes	National forest	Other public	Forest industry	Nonindustrial private
	Million cubic feet				
1953	148,470	9,766	4,574	27,785	106,345
1963	174,072	13,245	5,818	34,869	120,140
1982	223,913	18,806	7,397	41,236	156,474
1989	245,987	18,983	12,605	40,692	173,706
1999	261,601	20,873	16,043	41,722	182,964

Numbers in rows may not sum to totals due to rounding.
[a] Kentucky data and data for 1953 and 1963 are taken from Smith and others 2001. Except for Kentucky, data for 1982, 1989, and 1999 are based on FIA inventories conducted between 1972-82, 1982-89, and 1990-99, respectively.

Volume trends by forest type—The area of hardwood and mixed pine-hardwood stands has increased over the last 50 years, while the area of pine has declined. These changes in area caused changes in volume distributions by forest type (fig. 16.20). The volume in mixed pine-hardwood stands increased almost 8 percent between 1989 and 1999, while the volume in all hardwood stands increased 9 percent (table 16.18). The majority of the hardwood volume is in the oak-hickory forest type, which comprised around one-third of all growing-stock volume and approximately 60 percent of all hardwood volume in both years.

Table 16.18—Volume of growing stock on timberland by forest-type group and year, Southern United States[a]

	Year[b]	
Forest-type group	1989	1999
	Million cubic feet	
White-red-jack pine	1,327	1,778
Spruce-fir	25	16
Planted longleaf-slash	5,610	6,283
Natural longleaf-slash	8,960	7,450
Planted loblolly-shortleaf	9,877	17,791
Natural loblolly-shortleaf	54,224	47,261
Oak-pine	30,348	32,846
Oak-hickory	72,895	82,057
Oak-gum-cypress	43,530	46,511
Elm-ash-cottonwood	3,700	2,733
Maple-beech-birch	719	833
Nontyped	163	40
All groups	231,378	245,600

Numbers in columns may not sum to totals due to rounding.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1982-89 and 1990-99, respectively.

Southern pine growing-stock volumes increased only slightly between 1989 and 1999, from 78,671 million cubic feet to 78,785 million cubic feet. The area of southern pine timberland increased 3 percent during this period. Comparing natural southern pine stands to planted stands produces some interesting results. Natural longleaf-slash pine and natural loblolly-shortleaf pine are two of the four forest types that lost volume in the 1990s. Elm-ash-cottonwood forest and spruce-fir types also lost volume. Planted southern pine stands increased in volume by 55 percent from 1989 to 1999. These increases can be attributed to the Conservation Reserve Program. In 1989, pine plantations held 7 percent of the South's total growing-stock volume. By 1999, plantations accounted for 10 percent of the total growing-stock volume.

Volume trends for recent surveys—As noted earlier, Alabama and South Carolina experienced completion of new surveys during the assessment process. These data were not used in the tables and figures above. In order to provide the reader with current information, these numbers will be briefly discussed throughout the chapter. Tables and figures will not be used. Individuals wishing this information should attain the publications for these States.

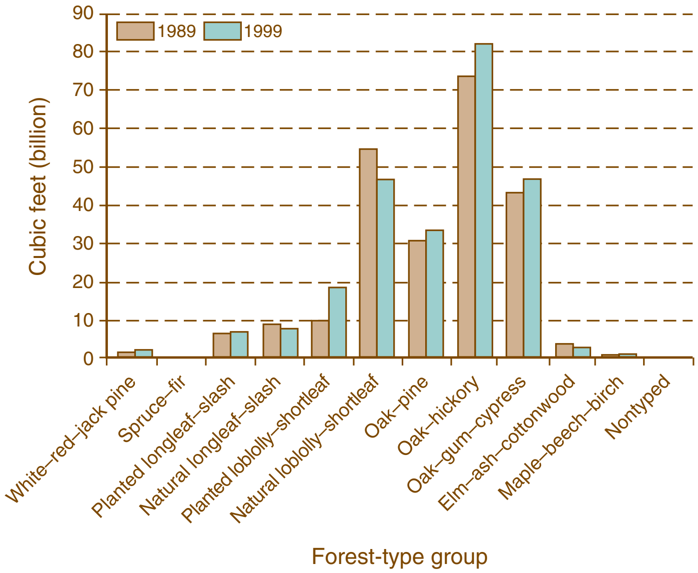

Figure 16.20—Volume of growing stock on timberland by forest-type group and year, Southern United States.

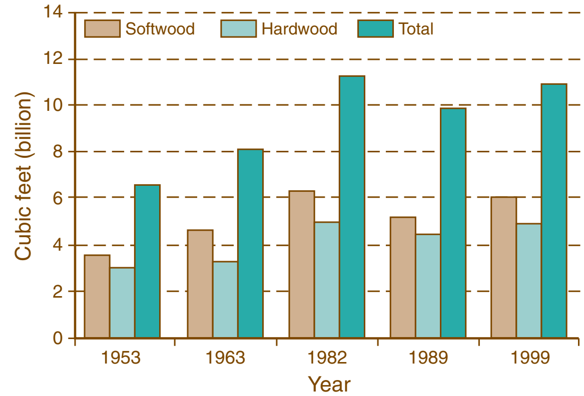

Figure 16.21—Average annual growth of growing stock on timberland by species group and year, Southern United States.

Alabama's softwood growing-stock volume increased 9 percent to 12.7 billion cubic feet between 1990 and 2000. Softwood growing-stock volume increased 23 percent on public lands to 1.1 billion cubic feet and increased by 22 percent to 9.2 billion cubic feet on NIPF lands. Driven by the reduction in landholdings in the State, softwood volume on forest industry lands decreased 26 percent to 2.4 billion cubic feet. Loblolly pine was the predominate species at 8.6 billion cubic feet, an increase of 25 percent since 1990. Alabama's softwood sawtimber totaled about 44 billion board feet, an increase of 5 percent since 1990.

Volume of hardwood growing stock in Alabama increased 17 percent to 15.2 billion cubic feet between 1990 and 2000. Hardwood volume increased 31 percent on public lands to 1.2 billion cubic feet, 25 percent on NIPF lands to 12.5 billion cubic feet, and decreased 31 percent on forest industry land to 1.4 billion cubic feet. Other red oaks were the predominate species group with 3.5 billion cubic feet. The inventory of hardwood sawtimber increased 33 percent to 45.7 billion board feet.

Merchantable volume of softwood growing stock in South Carolina increased from 8.0 billion cubic feet to 8.9 billion cubic feet, a rise of 11 percent. Loblolly pine volume increased 21 percent to 6.6 billion cubic feet, accounting for most of the increase in softwood volume. Since 1993, softwood volume on forest industry timberland increased in spite of losses of forest area under this ownership. Softwood volume on forest industry timberland rose 3.9 percent to 1.7 billion cubic feet within the State. Softwood volume on NIPF timberland increased from 5.2 billion cubic feet to 5.9 billion cubic feet. Significant reductions in the volume of slash and shortleaf pine occurred during the period, whereas the volume of longleaf pine remained relatively stable, dropping only 2.5 percent.

South Carolina's hardwood growing-stock volume increased during the latest survey as well, from 8.6 billion cubic feet to 8.8 billion cubic feet. The increase was greatest on NIPF land in cubic-foot terms, as hardwood inventory rose 208 million cubic feet to 6.9 billion cubic feet. Forest industry timberland experienced a 23-percent reduction in volume of hardwood live trees and was the only ownership to show a loss.

Trends in Growing-Stock Growth

The effects of reforestation and the resulting volume increases had a dramatic effect on growing-stock growth. As growing-stock volume increased during the first three survey periods after World War II, so did the average annual growth of growing stock (fig. 16.21). From 1953 to 1982, total growing-stock growth increased from 6,683 million cubic feet per year to 11,323 million cubic feet per year. During this period, softwood growing-stock growth increased by 73 percent, while that of hardwoods increased 65 percent (table 16.19). After 1982, growth of both softwoods and hard-

Table 16.19—Average net annual growth of growing stock on timberland by species group and year, Southern United States

Species group	1953	1963	1982	1989	1999
	Year[a]				
	Million cubic feet				
Softwood	3,641	4,699	6,315	5,113	5,970
Hardwood	3,041	3,394	5,009	4,662	4,892
All groups	6,683	8,093	11,323	9,775	10,862

Numbers in columns may not sum to totals due to rounding.
[a] Data for 1953, 1963, and 1982 are taken from Smith and others 2001. Except for Kentucky, data for 1989 and 1999 are based on FIA inventories conducted between 1982-89 and 1990-99, respectively. Kentucky data for both the 1989 and 1999 reporting years are from a 1988 FIA survey.

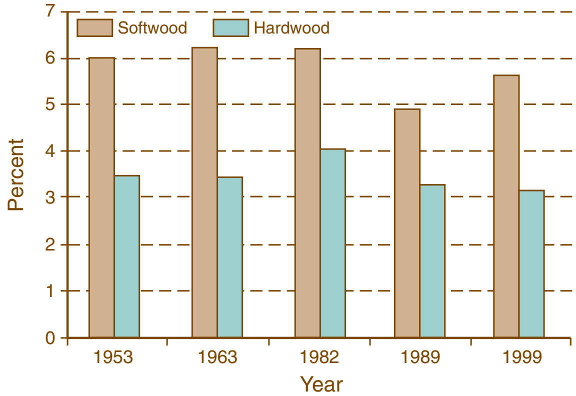

Figure 16.22—Rate of average annual growth of softwood and hardwood expressed as a percentage of growing stock, Southern United States.

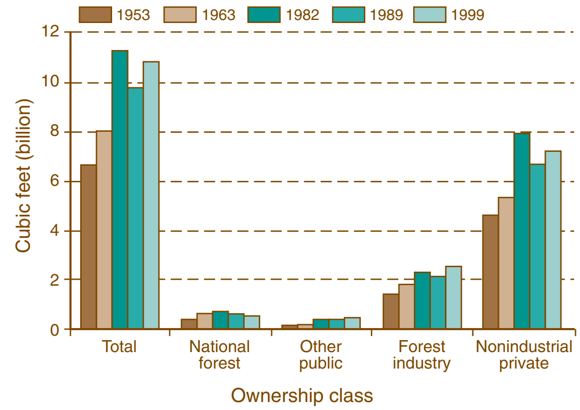

Figure 16.23—Average annual growth of growing stock on timberland by ownership class and year, Southern United States.

woods decreased slightly. From 1982 to 1999, average annual growth of softwoods declined 5 percent and hardwood growth decreased 2 percent. These data indicate that average annual growth of growing stock peaked in the 1970s and has since leveled off. After a decline in 1982, the subsequent survey showed a slight increase, 11 percent, in average annual growth. This increase corresponds to the time when gains in forest land in the South began to outpace losses (see section "Total change in forest land: additions and diversions"). Changes in timberland area often lead to changes in growing-stock growth. Therefore, this increase in area produced an increase in average annual growth of growing stock.

It is important to realize that while the rate of growth has slowed since the mid-1970s, growth is still occurring. In 1999, southern forests produced 10,862 million cubic feet of wood per year.

Dividing average annual growth by growing-stock volume creates a ratio that reveals the relationship between growth and standing volume. Historically, average annual softwood growth represented between 4.90 and 6.25 percent of the total softwood growing-stock volume (fig. 16.22). Hardwood growth rates fluctuated between 3.1 and 4.1 percent. The dip in average annual growth that occurred due to changes in timberland during the 1970s is clearly visible in the figure.

Growth trends by ownership—Because NIPF landowners control the majority of the timberland, growth on NIPF land mimics the trend of all landowners (fig. 16.23). Average annual growth of growing stock is the average increase in volume of growing-stock trees. It includes any volume from new trees or timberlands. Average annual growth of growing stock on NIPF land was 4,586 million cubic feet per year in 1953 and increased to 7,962 million cubic feet per year by 1982 (table 16.20). The growth rate dropped to 6,705 million cubic feet per year in 1989 before reaching the latest level of 7,271 million cubic feet per year.

Growth rates on forest industry land and national forests differ from the NIPF trend and from each other. Growth on national forests rose from 432 million cubic feet per year in 1953 to a peak of 667 million cubic feet per year in 1982. However, by 1999, the average annual growth on national forests was back to 511 million cubic feet per year. Conversely, growing-stock growth on forest industry land reached its highest point 2,618 million cubic feet per year in 1999.

The reason for the differing patterns of growth rates lies in the motives and management practices of the two different ownerships. Forest industry tries to maximize profit and therefore the volume cut in its operations. This approach leads to management practices that focus on smaller, younger trees that grow more vigorously. Thus, forest industries growth rates benefited in the 1950s, 1960s, and 1970s from early reforestation efforts and during the 1980s and 1990s from its focus on smaller, faster growing trees.

Table 16.20—Average net annual growth of growing stock on timberland by year and ownership class, Southern United States

		Ownership class			
Year[a]	All classes	National forest	Other public	Forest industry	Nonindustrial private
		Million cubic feet			
1953	6,683	432	209	1,456	4,586
1963	8,093	624	245	1,841	5,383
1982	11,323	667	400	2,294	7,962
1989	9,775	533	402	2,134	6,705
1999	10,862	511	462	2,618	7,271

Numbers in rows may not sum to totals due to rounding.
[a] Data for 1953, 1963, and 1982 are taken from Smith and others 2001. Except for Kentucky, data for 1989 and 1999 are based on FIA inventories conducted between 1982-89 and 1990-99, respectively. Kentucky data for both the 1989 and 1999 reporting years are from a 1988 FIA survey.

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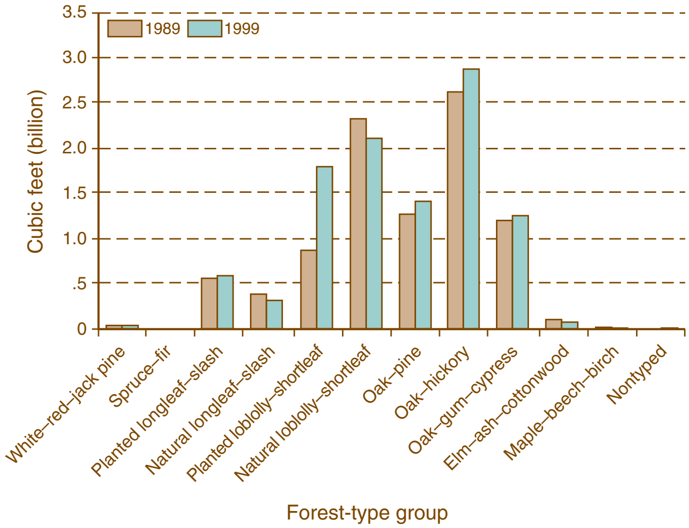


Figure 16.24—Average annual growth of growing stock on timberland by forest-type group and year, Southern United States.

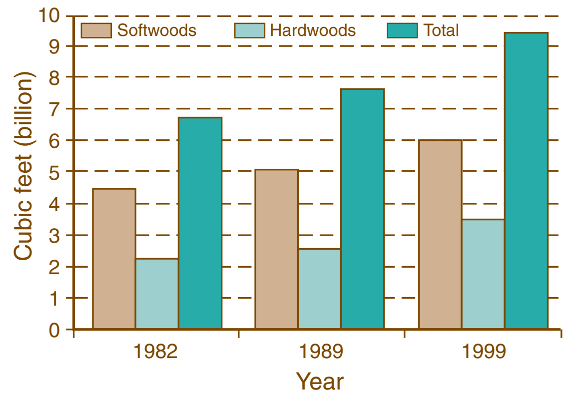


Figure 16.25—Average annual removals of growing stock on timberland by species group and year, Southern United States.

National forests are not managed to maximize timber production; they are managed to meet the needs of a diverse group of users. Many national forest management plans require long rotations. As these stands age, growth rates in them decline. Nevertheless, these stands produce fiber and wood products along with the other benefits for society.

Growth rates on other public timberland reached all-time highs in 1999. In fact, with the exception of the 1989 estimate, the average annual growth of growing stock for this land has increased steadily. A large part of the reason for this increased growth is land acquisition. From 1953 to 1999, 3.3 million acres of public land were acquired (table 16.2).

Average annual growth by forest type—Annual growth of growing stock in various forest types has always been of keen interest. The average annual growth of growing stock in loblolly pine plantations more than doubled between 1989 and 1999 (fig. 16.24 and table 16.21), going from 879 million cubic feet per year to 1,768 million cubic feet per year. Meanwhile, the growth of natural pine stands dropped from 2,646 million cubic feet per year to 2,412 million cubic feet per year. In 1999, planted stands accounted for 10 percent of the South's total growing-stock volume, but produced 23 percent of the average annual growth of growing stock.

Table 16.21—Average net annual growth of growing stock on timberland by forest-type group and year, Southern United States[a]

Forest-type group	Year[b] 1989	1999
	Million cubic feet	
White-red-jack pine	42	47
Spruce-fir	1	1
Planted longleaf-slash	568	597
Natural longleaf-slash	363	294
Planted loblolly-shortleaf	879	1,768
Natural loblolly-shortleaf	2,283	2,118
Oak-pine	1,287	1,419
Oak-hickory	2,635	2,873
Oak-gum-cypress	1,203	1,258
Elm-ash-cottonwood	109	72
Maple-beech-birch	19	15
Nontyped	3	18
All groups	9,391	10,478

Numbers in columns may not sum to totals due to rounding.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1982-89 and 1990-99, respectively.

Total growing-stock growth for the 12 Southern States rose from 9,391 million cubic feet per year to 10,478 million cubic feet per year. Forest types other than planted pine that gained growth were oak-pine with a 10-percent increase, oak-hickory with a 9-percent gain, and oak-gum-cypress with a 4.6 percent gain. The elm-ash-cottonwood, maple-beech-birch, and natural pine forest types all experienced decreases in average annual growth.

Average annual growth for latest surveys—Alabama's 2000 survey revealed net annual growth of softwood growing stock averaged 884 million cubic feet per year, an increase of 34 percent since the previous survey period. Softwood growth increased 91 percent on public lands, 36 percent on NIPF lands, and 25 percent on forest industry land. Planted stands accounted for half of the softwood growth. Net annual growth of hardwood growing stock averaged 596 million cubic feet, an increase of 5 percent since the previous survey period. Hardwood

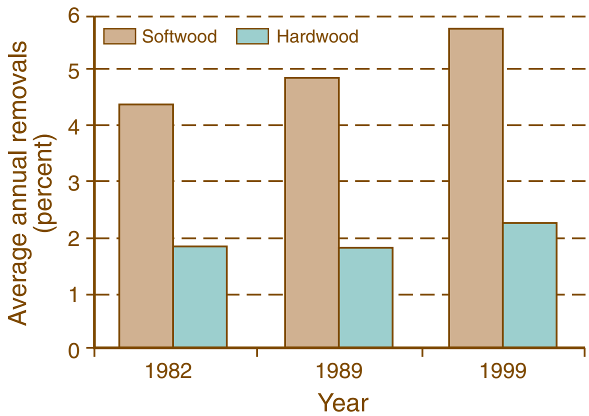


Figure 16.26—Rate of average annual removals of softwood and hardwood expressed as a percentage of growing stock, Southern United States.

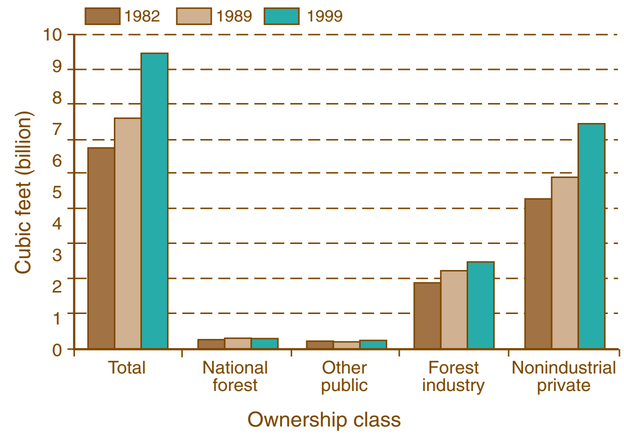


Figure 16.27—Average annual removals of growing stock on timberland by ownership class and year, Southern United States.

growth increased 25 percent on public lands and increased 12 percent on NIPF lands, but decreased 35 percent on forest industry lands.

South Carolina's net annual growth of softwood growing stock almost doubled since the State's last survey, going from 343 million cubic feet to 661 million cubic feet per year. Softwood growth was up on all ownerships, reflecting the recovery from Hurricane Hugo. Net growth of softwoods on forest industry timberland increased 61 percent and averaged 205 million cubic feet per year. Net annual growth of softwoods on NIPF land rose from an annual rate of 207 million cubic feet to 415 million cubic feet. Net annual growth of South Carolina's hardwood increased 61 percent to 292 million cubic feet. As with softwoods, hardwood net growth increased on all ownerships, including a 57-percent increase to 243 million cubic feet per year on NIPF land.

Status and History of Growing-Stock Removals

Average annual removals of growing stock are defined as the average annual sound-wood volume of growing-stock trees removed from the inventory by harvesting, cultural operations (such as timber stand improvement), land clearing, or changes in land use during the period between surveys. The latest RPA report has average annual removals data for three successive surveys of all 13 Southern States.

The data indicate that removals of both softwoods and hardwoods have increased with successive surveys (fig. 16.25), and softwoods consistently have been removed in greater quantities than hardwoods. In all surveys, softwoods have comprised at least 63 percent of total growing-stock removals (table 16.22). From 1982 to 1999, the average annual removals of softwood growing stock increased 36 percent, while hardwood removals rose 55.9 percent. Total growing-stock removals increased 42.5 percent.

The ratio of average annual removals to total growing-stock volume for hardwoods and softwoods reveals the same pattern (fig. 16.26). However, with each subsequent survey a larger portion of growing-stock volume is removed each year. In 1982, annual softwood removals represented 4.4 percent of the total softwood volume. By 1999, this had increased to 5.7 percent. The rate for hardwoods increased from 1.8 percent to 2.2 percent during the same time. This means that, over time, the removal and utilization of softwoods and hardwoods in relation to their current volumes has increased.

Removals by ownership—Removals of growing stock from public land have always been highly contentious because opinions differ on the role that public land should play in providing timber products and the amount of harvesting that is sustainable. All ownerships experienced an increase in removals between 1982 and 1999 (fig. 16.27). The removals on other public land went from 218 million cubic feet per year to 294 million cubic feet per year. Average annual removals on NIPF land increased 44 percent (table 16.23). Average annual removals on national forests grew 1 percent between 1982 and 1999 and peaked in 1989. Most of this increase occurred in the national forests in east Texas. Many of these removals are probably associated with salvage of dead trees after southern pine beetle (*Dendroctonus frontalis* Zimm.) outbreaks in the early 1980s. In 1999,

Table 16.22—Average annual removals of growing stock on timberland by species group and year, Southern United States

Species group	Year[a] 1982	1989	1999
	Million cubic feet		
Softwood	4,436	5,021	6,019
Hardwood	2,242	2,559	3,496
All groups	6,679	7,579	9,516

Numbers in columns may not sum to totals due to rounding.
[a] 1982 data are from Smith and others 2001. Except for Kentucky, data for 1989 and 1999 are based on FIA inventories conducted between 1982-89 and 1990-99, respectively. Kentucky data for both 1989 and 1999 reporting years are from a 1988 FIA survey.

private land accounted for 67.5 percent of all growing-stock removals.

Forest type and removal trends— Just as oak-hickory dominates all other forest types in terms of growing-stock volume and growth, it also leads in average annual removals (fig. 16.28). Oak-hickory's average annual removal rate of 3,195 million cubic feet per year in 1999 represents 34 percent of all growing-stock removals (table 16.24). In 1989, this forest type accounted for 33 percent of the removals. Oak-hickory and oak-pine combined have accounted for about half of all growing-stock removals.

Pine plantations accounted for approximately 19 and 16 percent of total growing-stock removals in both 1989 and 1999, respectively. These estimates are impressive considering that pine plantations accounted for only 6 percent of the total growing-stock volume in 1989 and 10 percent of that volume in 1999. Average annual removals in natural pine stands represent between 16 and 18 percent of total removals. Among forest types, only longleaf-slash pine stands experienced a decline in average annual removals between 1989 and 1999 for both natural and planted stands. Removals from planted longleaf-slash pine stands dropped from 403 million cubic feet per year to 376 million cubic feet per year. Natural longleaf-slash pine stands experienced a 4.8 percent drop in removals. Average annual removals from other forest types increased between 1989 and 1999:

Forest type	Change in removals
	%
White-red-jack pine	+144.4
Maple-beech-birch	+150.0
Oak-hickory	+ 31.2
Planted loblolly-shortleaf	+ 13.0
Oak-gum-cypress	+ 29.9

The large percentage changes in removal volumes for the white-red-jack pine and maple-beech-birch forest types can be attributed to the small area involved. Volumes and areas of these forest types are so small that any change in volume can produce a dramatic percentage change. The inclusion or removal of one plot in these forest types may produce large estimates of changes when expressed as a percentage.

Latest removal trends for Alabama and South Carolina—Average annual removals of Alabama's softwood growing stock averaged 890 million cubic feet, an increase of 24 percent since the previous survey period. Sixty-seven percent of these softwood removals were from NIPF land, 30 percent from forest industry land, and 3 percent from public lands. Softwood removals exceeded softwood growth by 0.7 percent. Planted stands accounted for 30 percent of the State's softwood growing-stock removals. Annual removals of Alabama's hardwood growing stock averaged 407 million cubic feet, an increase of 10 percent since the previous survey period. Eighty percent of hardwood removals were from NIPF land, 18 percent from forest industry land, and 2 percent from public land. Hardwood growth exceeded removals by 32 percent across the State.

Annual removals of South Carolina's softwood growing stock decreased 4 percent to 471 million cubic feet per year. Sixty-three percent, or 295

Table 16.23—Average annual removals of growing stock on timberland by year and ownership class, Southern United States

		Ownership class			
Year[a]	All classes	National forest	Other public	Forest industry	Nonindustrial private
	Million cubic feet				
1982	6,679	288	218	1,805	4,368
1989	7,579	317	171	2,293	4,798
1999	9,516	291	294	2,508	6,423

Numbers in rows may not sum to totals due to rounding.
[a] 1982 data are from Smith and others 2001. Except for Kentucky, data for 1989 and 1999 are based on FIA inventories conducted between 1982-89 and 1990-99, respectively. Kentucky data for both 1989 and 1999 reporting years are from a 1988 FIA survey.

Table 16.24—Average annual removals of growing stock on timberland by forest-type group and year, Southern United States[a]

	Year[b]	
Forest-type group	1989	1999
	Million cubic feet	
White-red-jack pine	9	22
Planted longleaf-slash	403	376
Natural longleaf-slash	209	199
Planted loblolly-shortleaf	1,032	1,166
Natural loblolly-shortleaf	1,174	1,297
Oak-pine	1,160	1,59
Oak-hickory	2,435	3,195
Oak-gum-cypress	850	1,104
Elm-ash-cottonwood	67	65
Maple-beech-birch	4	10
Nontyped	58	305
All groups	7,400	9,337

Numbers in columns may not sum to totals due to rounding.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1982-89 and 1990-99, respectively.

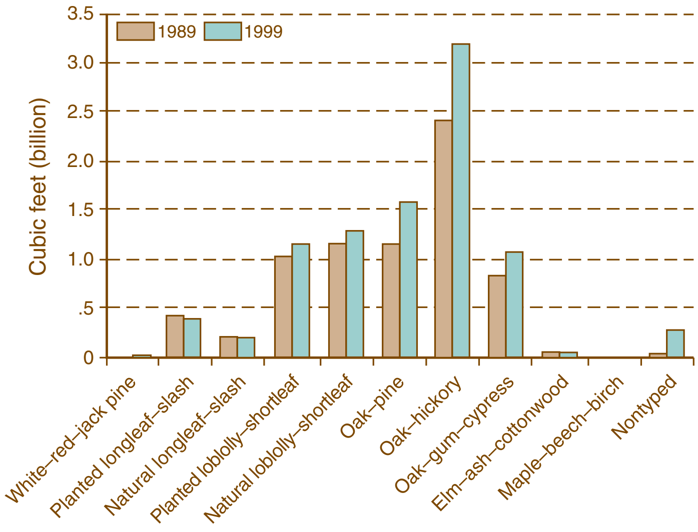


Figure 16.28—Average annual removals of growing stock on timberland by forest-type group and year, Southern United States.

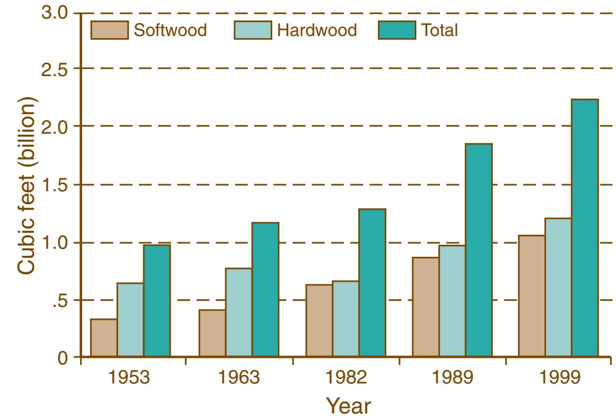


Figure 16.29—Average annual mortality of growing stock on timberland by species group and year, Southern United States.

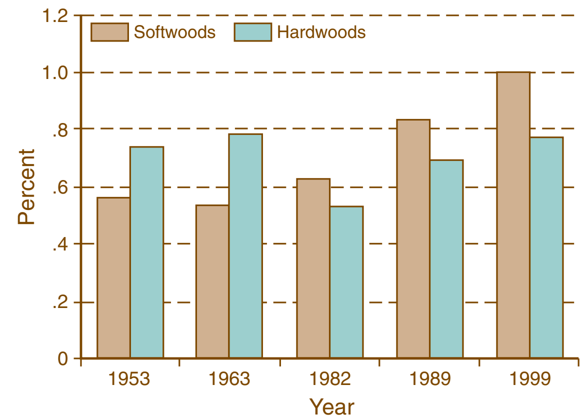


Figure 16.30—Rate of average annual mortality of softwood and hardwood expressed as a percentage of growing stock, Southern United States.

million cubic feet, of the softwood removals came from NIPF land. Softwood removals were down 9 percent on NIPF timberland. Forest industry timberland was the only ownership to show an increase in annual softwood removals, rising from 131 million cubic feet to 149 million cubic feet per year. Forest industry timberland accounted for 32 percent of total softwood removals. Removals of South Carolina's hardwood growing stock decreased 12 percent to 208 million cubic feet per year and was down on all ownerships except NIPF land. NIPF owners provided 83 percent, 173 million cubic feet, of the hardwoods removals volume, an increase of 1 percent. Hardwood removals from forest industry timberland dropped 24 percent to 33.5 million cubic feet per year.

Average Annual Mortality of Growing Stock

Average annual mortality is defined as the average annual sound-wood volume of growing-stock trees dying from natural causes between surveys.

Table 16.25—Average annual mortality of growing stock on timberland by species group and year, Southern United States

Species group	Year[a] 1953	1963	1982	1989	1999
	Million cubic feet				
Softwood	333	399	632	874	1,052
Hardwood	639	770	646	973	1,199
All groups	972	1,169	1,278	1,847	2,251

Numbers in columns may not sum to totals due to rounding.
[a] Data for 1953, 1963, and 1982 are taken from Smith and others 2001. Except for Kentucky, data for 1989 and 1999 are based on FIA inventories conducted between 1982-89 and 1990-99, respectively. Kentucky data for both the 1989 and 1999 reporting years are from a 1988 FIA survey.

From 1953 to 1999, total growing-stock mortality went from 972 million cubic feet per year to 2,251 million cubic feet per year (fig. 16.29). Softwood mortality increased 216 percent during this time, while hardwood mortality rose 88 percent.

In 1953 and 1963, hardwoods accounted for two-thirds of total growing-stock mortality. In 1982 average annual mortality rates for softwoods and hardwoods were nearly equal. In 1989 and 1999, hardwood mortality again exceeded softwood mortality, but only by 10 percent (table 16.25).

Investigation of the ratio of average annual mortality to standing volume reveals an interesting pattern. During the first two surveys, both softwoods and hardwoods experienced little change in this ratio (fig. 16.30). By 1982, the rate of morality decreased. Since then, hardwood and softwood mortality ratios have increased. The primary cause of this decline is most likely the amount of planting and timber management that was

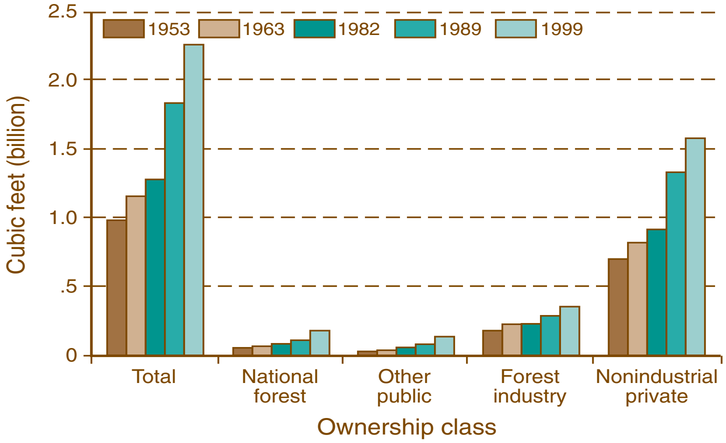


Figure 16.31—Average annual mortality of growing stock on timberland by ownership class and year, Southern United States.

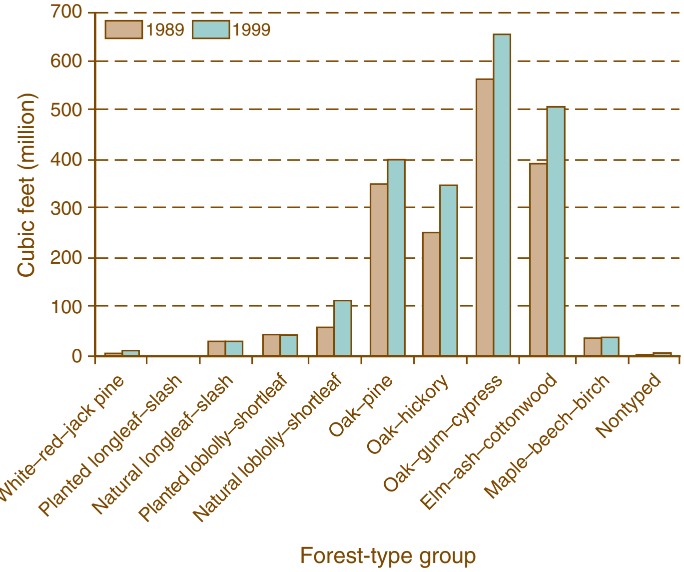


Figure 16.32—Average annual mortality of growing stock on timberland by forest-type group and year, Southern United States.

occurring in the late 1960s and early 1970s. Young, vigorous stands may experience low rates of mortality. However, if these stands are not actively managed, tree mortality may increase.

Causes of tree mortality are numerous and often difficult to identify. In 1999, diseases were responsible for 35 percent of all growing-stock mortality. Weather was the second greatest cause of tree mortality at 31 percent, followed by insects at 11 percent. The factor that had the greatest impact on average annual mortality was stand origin. Ninety-two percent of all growing-stock mortality occurred in natural stands. The other 8 percent occurred in planted stands. Loblolly and shortleaf pines accounted for 30 percent of the mortality volume in natural stands and 63 percent of the mortality volume in planted stands.

Ownership and average annual mortality—All ownerships experienced increased mortality, but forest industry experienced the lowest percentage increase (fig. 16.31). From 1953 to 1999, the average annual mortality almost doubled on industry land, going from 177.5 million cubic feet per year to 355 million cubic feet per year (table 16.26). All other ownerships experienced a doubling of average annual mortality over the same time span. The biggest increases were on public land. One reason mortality is relatively low on forest industry land is that intensive management permits the harvest of many weak or diseased trees before they die. Mortality is unusually high on public land because long rotations tend to lead to higher mortality rates.

Average annual mortality by forest type—The oak-gum-cypress forest type has the highest average annual mortality rate of all forest types, accounting for close to one-third of total mortality volume (fig. 16.32 and table 16.27). In 1989, the oak-gum-cypress forest type had an average annual mortality rate of 568.3 million cubic feet per year. In 1999, oak-gum-cypress accounted for 657.6 million cubic feet per year. The factor that best explains why oak-gum-cypress stands have such high mortality volumes is the lack of stand management. Many of these stands are not managed for timber production. Some are inaccessible or inoperable for logging due to frequent and long-term flooding. Thus, dying trees are left to succumb to natural mortality.

Hardwood and mixed pine-hardwood stands were responsible for nearly all growing-stock mortality in 1989 and 1999. Hardwood stands accounted for 91 percent of all average annual growing-stock removals in 1989, and 90 percent in 1999. This may seem odd, as the mortality rates between hardwoods and softwoods are fairly even. The answer to this dilemma

Table 16.26—Average annual mortality of growing stock on timberland by year and ownership class, Southern United States

		Ownership class			
Year[a]	All classes	National forest	Other public	Forest industry	Nonindustrial private
	- - - - - - - -	- - - - - - - -	*Million cubic feet*	- - - - - - - -	- - - - - - - -
1953	972	55	29	178	711
1963	1,169	68	41	227	833
1982	1,278	80	57	231	911
1989	1,846	136	98	292	1,321
1999	2,251	181	141	355	1,574

Numbers in rows may not sum to totals due to rounding.
[a] Data for 1953, 1963, and 1982 are taken from Smith and others 2001. Except for Kentucky, data for 1989 and 1999 are based on FIA inventories conducted between 1982-89 and 1990-99, respectively. Kentucky data for both the 1989 and 1999 reporting years are from a 1988 FIA survey.

lies in the allocation of forest type. Softwood forest types are assigned to plots that have at least 50 percent of their growing-stock volume in softwood species. Mixed pine-hardwood forest types are assigned to plots that have between 25 and 49 percent softwood growing stock. Hardwood forest types have less than 25 percent of their stocking in softwood species. Thus, hardwood as well as pine-hardwood stands have softwood species in them. Many of these softwood trees die from natural causes.

Average annual mortality for Alabama and South Carolina—The average annual mortality of Alabama growing stock has increased 40 percent to 276 million cubic feet since the previous survey period. Alabama's all-live hardwood and softwood mortality has increased 33 percent and 45 percent, respectively.

Much of the reason for South Carolina's increased net annual growth was due to declines in average annual mortality rates, which had been driven to abnormally high levels by Hurricane Hugo. Annual mortality of softwood growing stock decreased 72 percent, from 253 million cubic feet to 71 million cubic feet. Softwood mortality was down on all ownerships, declining 76 percent on NIPF land, from 162 million cubic feet to 39 million cubic feet per year. Mortality of softwoods on forest industry timberland fell 68 percent to 12 million cubic feet per year, and was down 62 percent on public timberland. Hardwood annual mortality in South Carolina was also down substantially, falling 47 percent to 81 million cubic feet per year. Hard-wood mortality on NIPF land declined 43 percent to 62 million cubic feet, and fell from 29 million cubic feet to 9 million cubic feet annually on forest industry timberland.

Southwide Growth-to-Removals Ratios

The ratio of growing stock removed annually to the amount of growth is a subject of great interest. A growth-to-removals (GR) ratio greater than one signifies that growth is exceeding removals. Conversely, a ratio of less than one denotes more volume is being removed than is being replaced by growth. For the past three survey cycles, GR ratios for both softwoods and hardwoods have decreased (fig. 16.33).

In 1982, the GR ratios for both total growing stock and hardwood growing stock exceeded 1.5. The softwood GR ratio was at 1.4. By 1999, the GR ratio for all species was 1.05, indicating that growth and removals were virtually equal. Average annual growing-stock removals of softwoods exceeded growth in 1999. However, this is the first time that average annual softwood removals exceeded average annual growth. The implications of this information are widely debated. Many view removals exceeding growth as over-exploitation of the resource. Others think of this as a temporary fluctuation, as we are approaching a GR ratio of one, which represents stability between growth and removals.

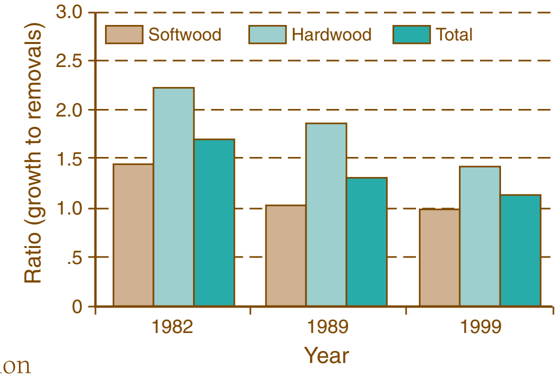


Figure 16.33—Average annual growth to average annual removals ratios of growing stock on timberland by species group and year, Southern United States.

Table 16.27—Average annual mortality of growing stock on timberland by forest-type group and year, Southern United States[a]

Forest-type group	Year[b] 1989	1999
	- - - - - - - *Million cubic feet* - - - - - - -	
White-red-jack pine	6	13
Planted longleaf-slash	0	0
Natural longleaf-slash	36	36
Planted loblolly-shortleaf	48	47
Natural loblolly-shortleaf	59	113
Oak-pine	351	399
Oak-hickory	254	345
Oak-gum-cypress	568	658
Elm-ash-cottonwood	391	503
Maple-beech-birch	38	40
Nontyped	4	7
All groups	1,758	2,162

Numbers in columns may not sum to totals due to rounding.
0 indicates a value of > 0 but < .5 for the cell.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1982-89 and 1990-99, respectively.

It is important to remember that the growth and removals estimates in this chapter are based on growing-stock trees. Any trees not meeting the minimum size requirement (5.0 inches d.b.h.) are excluded. Therefore, any interpretation of GR ratios should consider nonmerchantable trees and stands, and their impacts on future growth. In 1999, 14 percent of the South's timberland was in stands 0 to 7 years old (table 16.10). Most of these stands are composed of submerchantable-sized trees. An additional 9 percent of the South's stands are 8 to 12 years age old. Many of these stands also have yet to reach merchantable status. Planted stands 0 to 12 years old account for 9 percent of the timber base. These stands have the potential to greatly affect future standing volume and average annual growth. These stands will contribute to future growth as the trees in these stands reach 5 inches d.b.h.

Effects of Pine Plantations

on the South's Forests

The long-term repercussions of southern pine plantations are subject to interpretation. These forests increase the efficiency of timber production but also alter wildlife habitat.

The majority of plantation growing-stock volume is in softwoods. Of the 26,613.1 million cubic feet of wood in plantations, 91 percent is softwood. In fact, 65 percent of the growing-stock volume in plantations is in the shortleaf-loblolly pine species group. Conversely, natural stands are composed of only 36 percent softwoods. Most of the South's hardwood volume, however, is in natural stands (table 16.28).

How productive are southern pine plantations? The growth-to-volume ratio for plantation softwoods is 101 percent. It is derived by dividing the growth of plantation softwoods, 2,467 million cubic feet per year, by the total softwood volume, 24,234.1 million cubic feet. Total growth-to-volume ratio for plantations is 9.7 percent. The removals-to-volume ratio for plantations is 5.4 percent, while the mortality-to-volume ratio is 0.6 percent. Thus, softwoods plantations grow almost 10 percent of their total growing-stock volume annually, while 5.7 percent is removed each year. In 1999, growth of plantation softwoods

Table 16.28—Volume, average net annual growth, average annual removals, and mortality of growing stock on timberland by species and stand origin, Southern United States[a]

	Stand origin[b]							
	Natural				Plantation			
Species	Volume	Growth	Removals	Mortality	Volume	Growth	Removals	Mortality
	Million cubic feet							
Softwood								
Longleaf-slash pine	9,698	423	586	76	6,233	652	571	43
Loblolly-shortleaf pine	51,583	2,550	3,546	599	17,335	1,764	788	115
Other pine	8,609	263	341	155	389	38	25	2
Eastern white-red pine	1,884	60	36	13	239	11	5	2
Spruce-fir	24	1	—	1	—	—	—	—
Eastern hemlock	628	19	6	2	2	0	—	0
Cypress	6,410	112	82	19	12	0	0	—
Other softwood	1,231	51	18	14	24	1	0	—
Total softwoods	80,066	3,478	4,616	877	24,234	2,467	1,389	162
Hardwood								
Select white oak	14,750	480	347	57	246	10	5	2
Select red oak	6,993	246	160	52	68	5	2	0
Other white oak	12,361	326	221	67	112	3	2	1
Other red oak	26,254	975	833	313	591	31	14	3
Hickory	9,744	247	182	79	104	2	2	1
Yellow birch	95	1	0	1	—	—	—	—
Hard maple	1,218	42	13	4	2	—	—	—
Soft maple	7,371	266	136	59	102	6	1	1
Beech	1,843	46	32	7	22	0	0	0
Sweetgum	16,142	555	526	129	541	34	16	3
Tupelo-blackgum	11,096	227	187	58	91	3	2	0
Ashes	4,048	111	66	44	20	1	0	0
Cottonwoods-aspen	578	11	18	12	18	2	6	—
Basswood	513	11	5	2	3	0	—	—
Yellow-poplar	13,361	488	310	58	252	18	5	0
Black walnut	399	9	6	2	2	0	—	—
Other soft hardwood	9,845	317	197	128	178	12	3	1
Other hard hardwood	2,109	43	35	40	26	1	1	0
Noncommercial	199	9	—	—	2	0	—	—
Total hardwoods	138,918	4,408	3,273	1,110	2,379	127	58	12
All species	218,984	7,886	7,889	1,988	26,613	2,594	1,447	174

Numbers in columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell; 0 indicates a value of > 0 but < .5 for the cell.
[a] Excludes Kentucky.
[b] Data are based on FIA surveys conducted between 1990 and 1999.

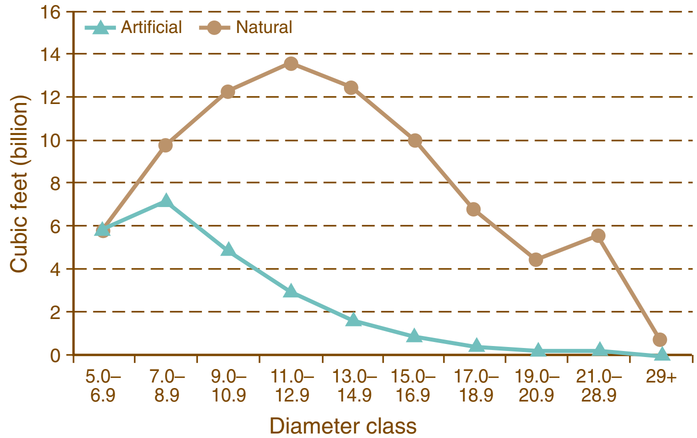


Figure 16.34—Volume of softwood growing stock on timberland by stand origin and diameter class, Southern United States, 1999.

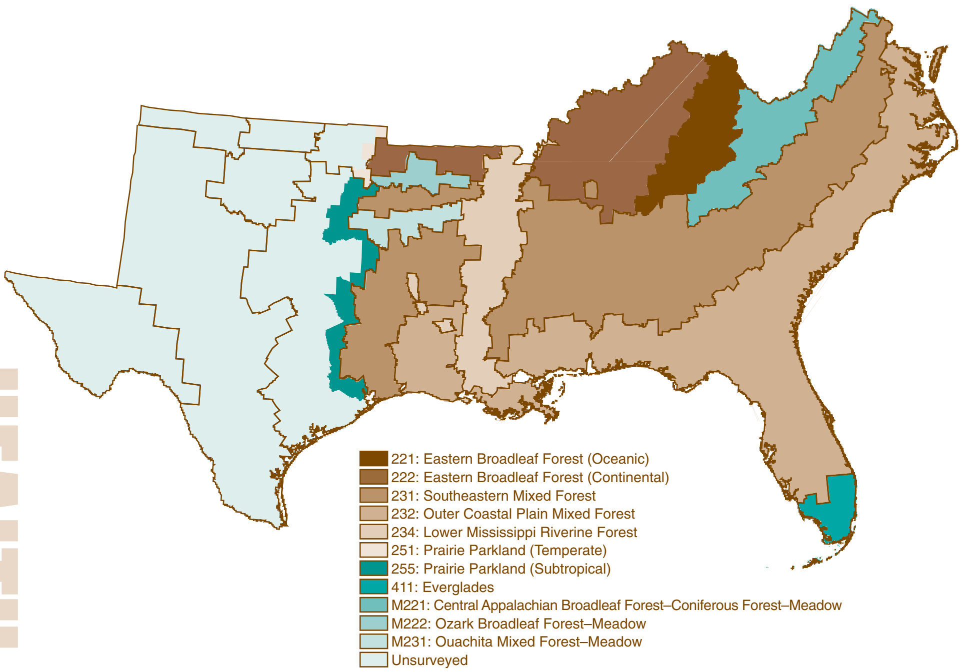


Figure 16.35—Ecological Provinces of the Southern United States.

exceeded removals. Natural stands have a growth-to-volume ratio of 3.6 percent. The removals-to-volume ratio for natural softwoods is also 3.6 percent, while the mortality-to-volume ratio is 0.9 percent. Currently, removals of softwood growing stock exceed growth of growing stock in natural stands. Plantations are responsible for 41.5 percent of all softwood growth in the South, despite the fact that they account for only 10.8 percent of the total growing-stock volume. Mortality is also higher in natural stands, probably because management is more intensive in plantations and weak or diseased trees are harvested in thinnings before they die.

Another topic that often creates heated discussion is the contrast in diameter distributions between natural stands and plantations. Natural stands have more volume due to the large amount of area they occupy. However, the diameter distributions of natural stands and planted stands differ considerably. In natural stands, the 11.0- to 12.9-inch diameter class has the greatest amount of volume (fig. 16.34). The diameter class with the greatest volume in planted stands is 7.0-8.9 inches. This is the size of chip-n-saw trees. From this point on, the curve drops. By the 17.0- to 18.9-inch class, little volume remains.

The general conclusions that can be formed from table 16.28 and figure 16.34 are that plantations are comprised mainly of softwoods, particularly loblolly and shortleaf pines. Plantations produce more growing-stock volume than natural stands in relation to the standing volume. Natural stands tend to have a greater variety of species, especially hardwoods, and have larger diameter distributions.

Rosson (1999) found similar results in a 30-year study of Arkansas and Mississippi. He used FIA data that covered three decades (four measurement periods) and over 2,500 plots per measurement period to investigate the effects of pine plantations on species richness and species evenness for an entire State. Species richness for the study was defined as the number of species found on a sample plot. The study showed that pine plantations had a notable impact on tree species richness at the State level. In this study, Arkansas plantations had 14.1 percent lower species richness, and Mississippi plantations had 28.9 percent lower species richness than natural stands. Rosson reported that tree species richness declines as plantations replace harvested natural stands. Plots that had harvesting activity over the same study period experienced increases in tree species richness. Species richness on nonharvested plots increased 21.6 percent in Arkansas and 43.8 percent in Mississippi over the 30-year period.

Southern Forest Ecosystems: Province Ecological Units

Framers of the Southern Forest Resource Assessment agreed to report results for ecological units as well as for more traditional units. The three higher levels of ecological units consist of Domain, Division, and Province (McNab and Avers 1994). The Province, which represents the regional scale, is the level at which FIA data are aggregated, analyzed, and discussed in this chapter.

Distribution of timberland by Province and forest type—Portions of 11 Ecological Provinces occur in the South (fig. 16.35). FIA data are organized by county, so it was not possible to follow Province boundaries exactly. Instead, each county was mapped into the Province that encompassed the greater portion of the county area.

The distribution of the South's timberland area by forest type and Province is shown in figures 16.36A and 16.36B and table 16.29. The largest forested Province in the South is the Southeastern Mixed Forest, which has 121 million acres of land, including 80 million acres of timberland. The Province extends from northern Virginia to eastern Texas and contains acreage of every major forest type in the South, except spruce-fir, which is limited to the Central Appalachian Broadleaf Forest Province. Oak-hickory forest types are the most abundant hardwoods and occupy 27 million acres or 34 percent of the timberland area in the Southeastern Mixed Forest Province (fig. 16.36B). Nearly 1 out of every 3 acres of oak-hickory in the South are in this ecological unit. This Province also contains 28 million acres of loblolly-shortleaf pine—56 percent of the area of these forest types in the southern region (fig. 16.36A).

The South's Atlantic and Gulf Coasts comprise the Outer Coastal Plain Mixed Forest Province. Stretching from coastal Virginia to southern Louisiana and extreme eastern Texas, the 101 million acres in this ecological unit support 59 million acres of timberland. Forty-seven percent of the timberland in the Outer Coastal Plain Mixed unit is in pine types, including 13 million acres, 92 percent, of the longleaf and slash pine forests found in the South. This unit also encompasses 15 million acres of loblolly-shortleaf pine. Primary hardwood forest types are oak, gum, and cypress, which occupy 14 million acres, nearly half of the oak-gum-cypress forests in the region.

The largest of the South's three mountain provinces is the Central Appalachian ecological unit with 23 million acres. As the name implies, this Province includes the Appalachian Mountains of northern Virginia south to northeast Georgia. Within its boundaries are 15 million acres of timberland, including all the primary forest types in the South, except longleaf and slash pines. Most of the timberland in the Central Appalachian Province, 10 million acres, is occupied by the oak-hickory type. Oak-pine forests account for 2 million acres, and maple-beech-birch stands occupy another 374,000 acres. Less than 10 percent of the area is in loblolly and shortleaf pine forest types. The white-red-jack pine forest type group occupies 543,000 acres in this Province. Although the type includes red and jack pines, white pine is the predominant species in the South.

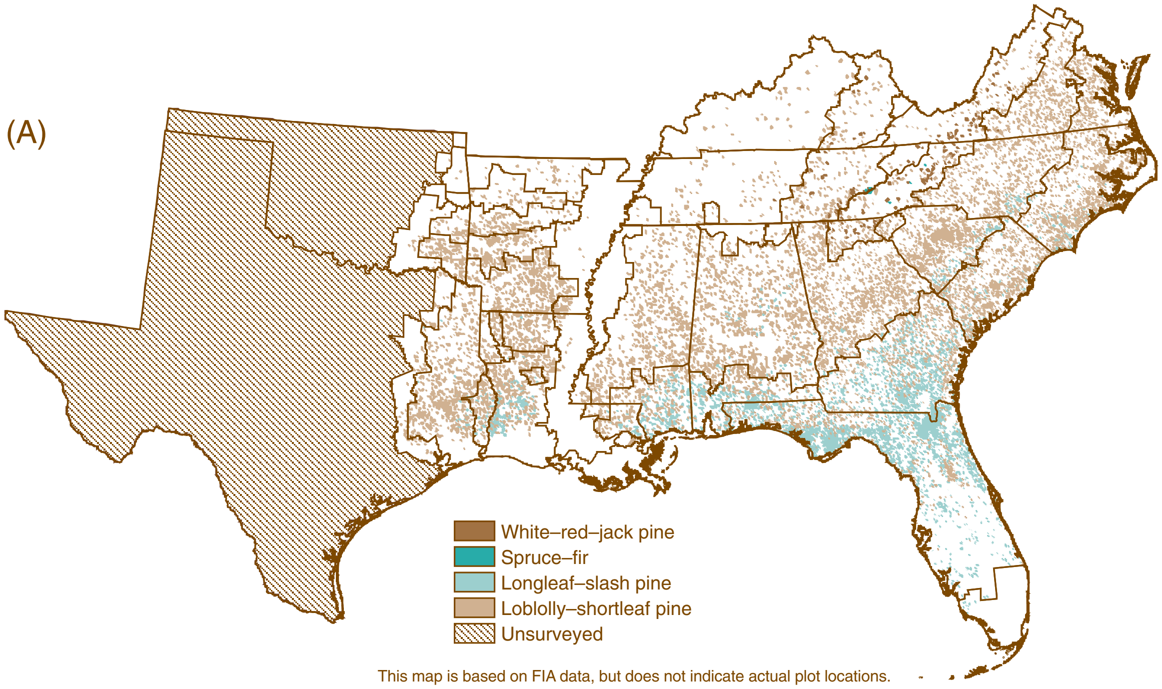
Planted and natural pine and oak-pine stands by Province—In 1999, planted pine/oak-pine stands occupied 34 million acres throughout the South. Some 31 million acres were in the Southeastern Mixed and Outer Coastal Plain Mixed Provinces (table 16.30). Planted stands account for nearly one-quarter of the timberland area in the two Provinces combined. Natural pine/oak-pine acres still outnumber the planted stands in these units, occupying 48 million acres. In the Southeastern Mixed Province the ratio of natural to planted pine/oak-pine is 2-to-1. This is not the case for the Outer Coastal Plain Mixed, where there are just 1.1 acres of natural pine/oak-pine for every planted acre. Hardwoods occupy the remaining area in both units, 59 million acres.

Planted pine/oak-pine stands are a minor component in the other Provinces, except for the Ouachita Mixed Forest unit, where they occupy 1 million of the 4 million acres of timberland. The 3 million acres that make up the rest of the Province are split evenly between natural pine/oak-pine and hardwood forest types.

Table 16.29—Area of timberland by Province and forest-type group, Southern United States, 1999

Province code	Province[a]	All groups	White-red-jack pine	Spruce-fir	Long-leaf-slash pine	Loblolly-shortleaf pine	Oak-pine	Oak-hickory	Oak-gum-cypress	Elm-ash-cotton-wood	Maple-beech-birch	Non-typed
		Forest-type group[b]										
		Thousand acres										
221	Eastern Broadleaf (Oceanic)	11,025	120	—	—	1,171	1,081	8,321	38	84	198	13
222	Eastern Broadleaf (Continental)	18,285	8	—	—	1,149	1,745	13,469	829	542	483	60
231	Southeastern Mixed	79,538	21	—	993	27,852	14,798	26,811	8,251	715	1	97
232	Outer Coastal Plain	58,869	—	—	12,500	15,001	8,227	8,882	13,885	252	—	121
234	Lower Miss. Riverine	7,928	—	—	21	1,016	480	1,368	4,370	642	—	31
251	Prairie Parkland (Temperate)	279	—	—	—	7	—	253	19	—	—	—
255	Prairie Parkland (Subtropical)	3,332	—	—	—	490	371	1,668	685	90	—	29
411	Everglades	191	—	—	28	—	8	10	144	—	—	—
M221	Central Appalachian	14,466	543	13	—	1,279	1,857	10,310	13	74	374	4
M222	Ozark Broadleaf	2,621	—	—	—	304	441	1,820	44	12	—	—
M231	Ouachita Mixed	4,203	—	—	—	1,732	967	1,291	202	11	—	—
	Total	200,736	692	13	13,542	50,001	29,974	74,202	28,481	2,420	1,057	355

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] McNab and Avery 1994.
[b] Data are based on FIA surveys conducted between 1990 and 1999. Estimates include nonstocked acres.



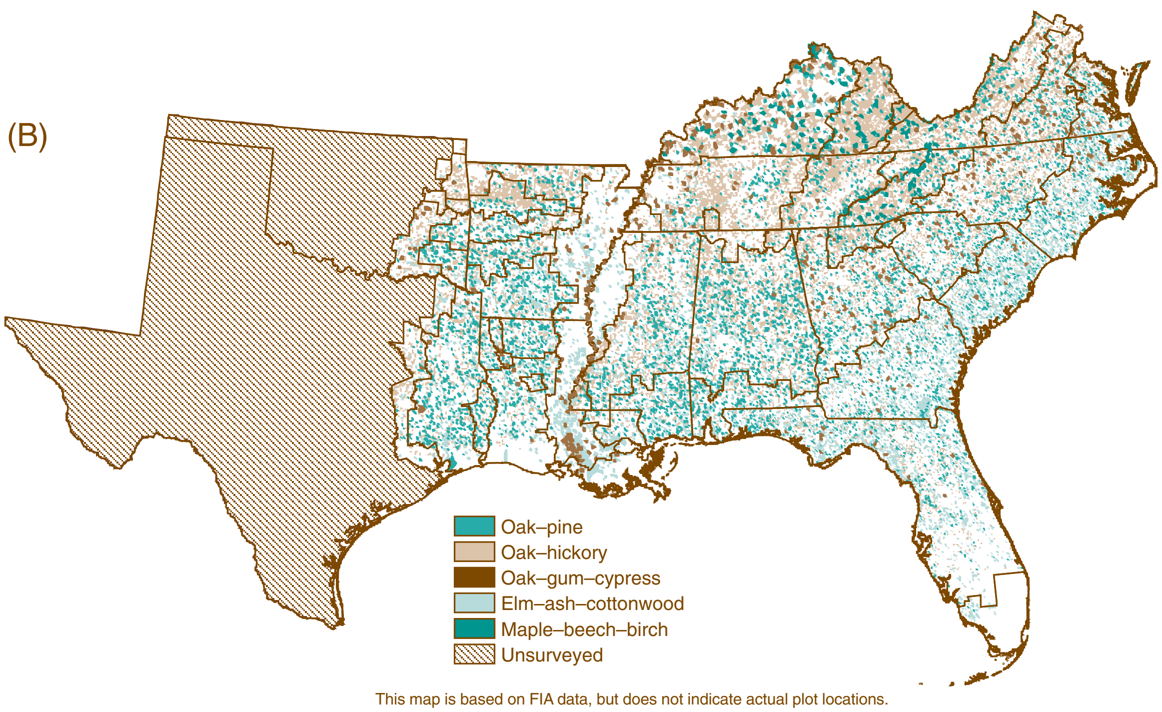
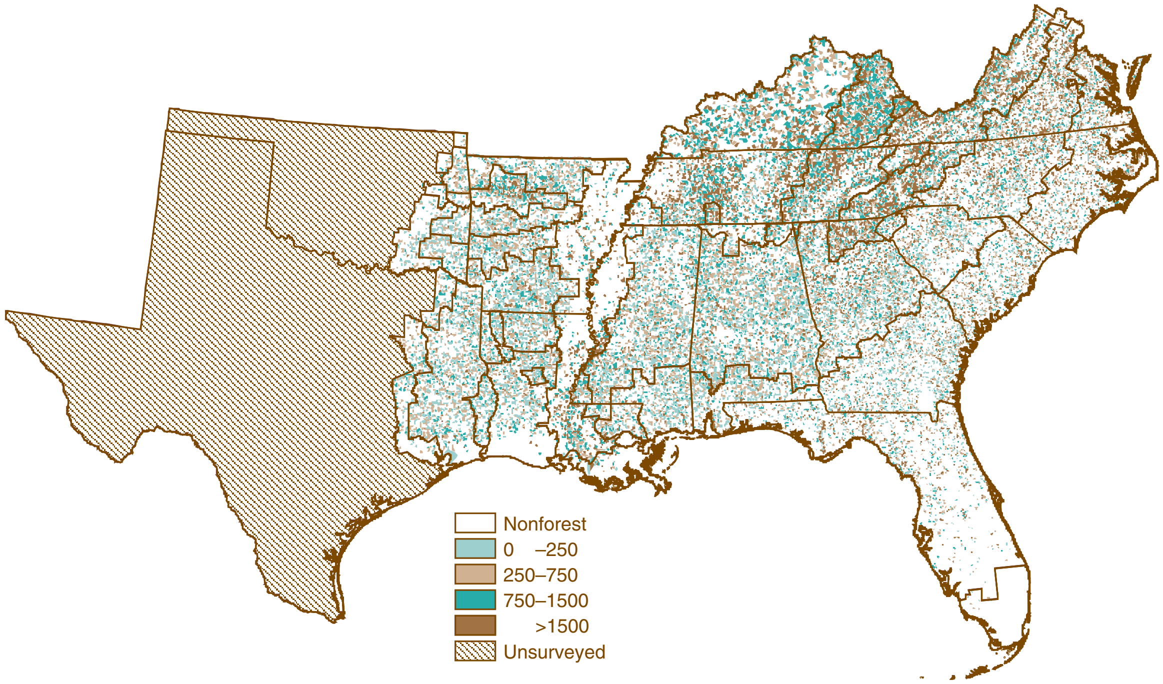


Figure 16.36—Distribution of timberland by Province and (A) softwood forest-type group and (B) hardwood forest-type group, Southern United States, 1999.

Distribution of timberland by Province and ownership—Timberland ownership by Ecological Province is shown in table 16.31. Timberland owned by private individuals is well represented in each of the 11 Provinces. Individuals control more than half the timberland acres in all but two Provinces and own as much as 82 percent of the Eastern Broadleaf Forest (Continental) unit and 85 percent of the Everglades Province. The two units where private individuals own less than half of the timberland are the Outer Coastal Plain Mixed Province, 48 percent, and the Ouachita Mixed Province, 30 percent.

Forest industry and corporate ownerships are concentrated in the Outer Coastal Plain Mixed and Southeastern Mixed Provinces, as are national forests and other public timberlands. Industry ownership in the two units combined totals 34 million acres, which is 86 percent of all industry timberland in the South. Seventy percent of all corporate timberland, 13 million acres, is in these Provinces.



This map is based on FIA data, but does not indicate actual plot locations.

Figure 16.37—Distribution of hardwood live-tree volume per acre of timberland by Province, Southern United States,1999.

National forest timberland in the Outer Coastal Plain and Southeastern Mixed Provinces combined, amounts to 5 million acres, or 47 percent of the national forest timberland in the South. Another 28 percent, or 3 million acres of national forest land is in the Central Appalachian Province. This Province contains the George Washington and Jefferson National Forests in Virginia and major portions of the Pisgah and Nantahala National Forests in North Carolina. Corporations control about 2 million acres in the Central Appalachian Province.

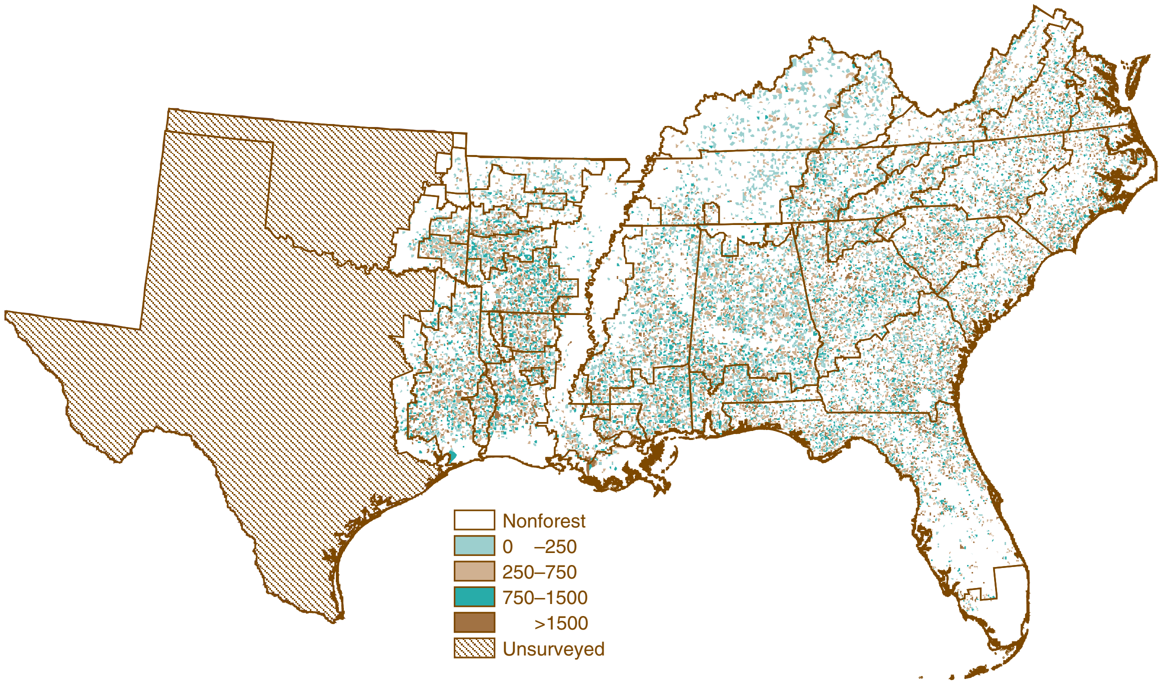
Table 16.30—Area of timberland by Province for planted pine/oak-pine, natural pine/oak-pine, and hardwood, Southern United States, 1999

Province code	Province[a]	All types	Forest management type[b]		
			Planted pine/ oak-pine	Natural pine/ oak-pine	Hard-wood
		Thousand acres			
221	Eastern Broadleaf (Oceanic)	11,025	291	2,081	8,653
222	Eastern Broadleaf (Continental)	18,285	398	2,504	15,384
231	Southeastern Mixed	79,538	14,631	29,033	35,875
232	Outer Coastal Plain	58,869	16,668	19,061	23,140
234	Lower Miss. Riverine	7,928	411	1,106	6,411
251	Prairie Parkland (Temperate)	279	—	7	272
255	Prairie Parkland (Subtropical)	3,332	101	760	2,471
411	Everglades	191	—	37	154
M221	Central Appalachian	14,466	332	3,359	10,774
M222	Ozark Broadleaf	2,621	121	623	1,877
M231	Ouachita Mixed	4,203	1,194	1,505	1,504
	Total	200,736	34,147	60,075	106,514

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] McNab and Avery 1994.
[b] Data are based on FIA surveys conducted between 1990 and 1999. Estimates include nonstocked and nontyped acres.

Live-tree volume on timberland by Province—Hardwood live-tree volume density is shown in figure 16.37. This map illustrates that the Appalachian, Smoky, and Ozark Mountain Ranges have the highest hardwood densities in the South. Conversely, the Mississippi Delta, south Florida everglades, and the extreme western edge of the survey range have little hardwood volume. These areas also have little softwood volume (fig. 16.38). Additionally, the Eastern Broadleaf Forest (Continental) and parts of the Appalachian Mountain units have low softwood densities. Softwood volume also is low in the Blackland Prairie, which runs through Alabama and Mississippi. The highest softwood densities are in central Louisiana and southern Arkansas, as well as the northwestern edge of the Outer Coastal Plain Mixed Province.

Investigating total volume by Province reveals the relationship between area and volume. The Southeastern Mixed and Outer Coastal Plain Mixed Provinces contain a majority of timberland area and volume. The Southeastern Mixed Province has



This map is based on FIA data, but does not indicate actual plot locations.

Figure 16.38—Distribution of softwood live-tree volume per acre of timberland by Province, Southern United States, 1999.

40 percent of the timberland area and 41 percent of the total growing-stock volume (table 16.32).

Average net annual growth and removals of live timber by Province—The Southeastern Mixed Province dominates the South in net annual growth and removals of live trees (table 16.33). This Province, which accounts for 40 percent of the total timberland area in the South, is responsible for 50 percent of the South's average net annual growth and 59 percent of its average net annual removals. The Southeastern Mixed and Outer Coastal Plain Mixed Provinces are the only two in which softwood removals exceed growth. With the exception of the Everglades Province, growth exceeds or equals removals for both softwood and hardwood species in all other Provinces.

Table 16.31—Area of timberland by Province and ownership class, Southern United States, 1999

Province code	Province[a]	All classes	Ownership class[b]					
			National forest	Miscellaneous Federal	Other public	Forest industry[c]	Private individual	Corporate
		Thousand acres						
221	Eastern Broadleaf (Oceanic)	11,025	926	124	358	778	7,672	1,168
222	Eastern Broadleaf (Continental)	18,285	312	679	437	761	15,068	1,029
231	Southeastern Mixed	79,538	2,958	1,660	1,207	16,682	50,513	6,519
232	Outer Coastal Plain	58,869	2,439	1,579	2,225	17,698	28,027	6,902
234	Lower Miss. Riverine	7,928	251	308	513	1,490	3,996	1,370
251	Prairie Parkland (Temp.)	279	—	46	7	—	190	36
255	Prairie Parkland (Subtrop.)	3,332	—	104	47	200	2,648	333
411	Everglades	191	—	—	9	—	162	20
M221	Central Appalachian	14,466	3,188	111	292	399	8,805	1,672
M222	Ozark Broadleaf	2,621	776	31	37	90	1,598	90
M231	Ouachita Mixed	4,203	709	83	59	1,930	1,254	169
	Total	200,736	11,558	4,724	5,190	40,027	119,932	19,306

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] McNab and Avery 1994.
[b] Data are based on FIA surveys conducted between 1990 and 1999.
[c] Includes timberland under long-term lease.

FIA Procedures

This section describes the inventory procedures used to collect forest resource data in Southern States. Dates of surveys for each State are in the section, 1970s to 1999. Inventory procedures between 1972 and 1995 differed slightly from procedures in 1997 through 1999. Descriptions of both methods follow.

Inventory procedures between 1972 and 1995—Estimates of forest and nonforest areas were based on the ground classification of sample clusters systematically spaced on the most recent aerial photographs. A subsample of 16-point clusters was ground-checked, and a linear regression was fitted to the data to develop the relationship between the photo and ground classification of the subsample. This procedure provided a means for adjusting initial estimates of area for changes in land use since date of photography and for errors in photointerpretation.

Estimates of timber volume and forest classification were based on measurements recorded at ground-sample locations systematically distributed on timberland. The plot design at each location was based on a cluster of 10 points. In most cases, variable plots, established by using a basal-area factor of 37.5 square feet per acre, were systematically spaced in a single forest condition at 5 of the 10 cluster points. Trees less than 5 inches d.b.h. were tallied on a fixed-radius plot at the center of each point.

Equations prepared from detailed measurements collected on standing trees in each State, and similar measurements taken throughout the Southeast, were used to compute the volume of individual tally trees. A mirror caliper and sectional aluminum poles were used to obtain the additional measurements required to construct volume equations. Forest biomass was estimated with equations developed by the Ecology and Genetics of Southern Pine Ecosystems Research Work Unit of the SRS in Athens, GA. In addition, felled trees were measured at several active cutting operations in each State to provide utilization factors for the different timber products and species groups, and to supplement the standing-tree volume study.

Table 16.32—Volume[a] of live timber on timberland by Province and species group, Southern United States, 1999

Province code	Province[b]	All groups	Species group	
			Softwood	Hardwood
		Million cubic feet		
221	Eastern Broadleaf (Oceanic)	18,944	3,285	15,658
222	Eastern Broadleaf (Continental)	25,323	2,211	23,111
231	Southeastern Mixed	108,170	48,944	59,226
232	Outer Coastal Plain	77,694	39,802	37,892
234	Lower Miss. Riverine	13,332	3,135	10,197
251	Prairie Parkland (Temperate)	253	9	244
255	Prairie Parkland (Subtropical)	2,788	830	1,958
411	Everglades	212	183	30
M221	Central Appalachian	30,142	5,423	24,720
M222	Ozark Broadleaf	3,299	677	2,622
M231	Ouachita Mixed	4,645	2,727	1,917
	Total	284,801	107,225	177,575

Numbers in rows and columns may not sum to totals due to rounding.
[a] Data are based on FIA surveys conducted between 1990 and 1999.
[b] McNab and Avery 1994.

Table 16.33—Average net annual growth and removals of growing stock[a] on timberland by Province, softwood and hardwood, Southern United States, 1999

Province code	Province[b]	Net annual growth[c]			Annual timber removals[c]		
		Total	Softwood	Hardwood	Total	Softwood	Hardwood
		Million cubic feet					
221	Eastern Broadleaf (Oceanic)	491	100	391	203	75	127
222	Eastern Broadleaf (Continental)	672	90	582	394	59	335
231	Southeastern Mixed	4,866	2,906	1,960	4,675	3,063	1,613
232	Outer Coastal Plain	3,300	2,324	976	3,275	2,380	895
234	Lower Miss. Riverine	429	129	300	338	130	208
251	Prairie Parkland (Temperate)	12	0	12	2	—	2
255	Prairie Parkland (Subtropical)	124	57	67	66	46	19
411	Everglades	3	4	-1.0	5	4	1
M221	Central Appalachian	633	149	485	374	132	242
M222	Ozark Broadleaf	93	30	63	37	20	17
M231	Ouachita Mixed	239	182	57	147	109	38
	Total	10,862	5,970	4,892	9,515	6,019	3,496

Numbers in rows and columns may not sum to totals due to rounding.
A dash (—) indicates no sample for the cell.
[a] Excludes trees < 5.0 inches in diameter at breast height.
[b] McNab and Avery 1994.
[c] Data are based on FIA surveys conducted between 1990 and 1999.

In each State, growth, removals, and mortality were estimated from the remeasurement of permanent sample plots established at the time of the previous inventory. Periodic surveys of timber products output conducted in cooperation with State agencies, along with the annual pulpwood production study for the South, provided additional information for breakdowns of removals by product.

Ownership information was collected from correspondence, public records, and local contacts in each Southern State. In counties where the sample missed a particular ownership class, temporary samples were added and measured to describe forest conditions in the ownership class.

All field data were sent to the Southern Research Station (SRS) FIA Unit for editing and were stored for processing. Final estimates were based on statistical summaries of the data.

Inventory methods for Georgia (1997) and Tennessee (1999)—The SRS-FIA unit currently uses a two-phase sample of aerial-photo points and permanent ground plots. The area of forest land in each county is determined by interpreting aerial-photo point clusters. Initial estimates of forest and nonforest land are based on the classification of sample clusters systematically spaced on the most recent aerial photographs. A subsample of the photo clusters is ground-checked so initial area estimates can be adjusted for changes in land use since the date of photography and for errors in photo interpretation.

The plot design at each ground sample location is based on a cluster of four points spaced 120 feet apart. Each point is the center of a 1/24-acre circular subplot used to sample trees 5.0 inches d.b.h. and larger. A 1/300-acre circular microplot, located at the center of the subplot, is used to sample trees 1.0 through 4.9 inches d.b.h. and seedlings (trees less than 1.0 inch d.b.h.). These fixed-radius sample plots are located without regard to land use or forest cover. Forest and nonforest condition classes are delineated and recorded. Condition classes are defined by six attributes: land use, forest type, stand origin, stand size, stand density, and major ownership category. All trees tallied were assigned to their respective condition class.

Estimates of timber volume and forest classification are derived from tree measurements and classifications made at the ground sample locations. Volumes for individual tally trees are computed using equations for each of the major species in the State. The equations were developed from detailed measurements collected on standing trees in each State and throughout the region.

Growth, removals, and mortality are estimated from the remeasurement of permanent sample plots established in the previous inventory. Plot design for the previous inventory has already been described.

Conclusions

The South's forests of today are drastically different from those present 100 or 200 years ago, and they continue to change. Human impacts from centuries of use have forever changed the character and extent of the South's forests. The absence of fire, combined with extensive logging and agricultural practices, resulted in the loss of vast expanses of open, park-like stands of timber. By 1900, much of the South's landscape was composed of cutover woodlands and highly eroded farmlands. Decades of abuse led to massive soil erosion in many parts of the South, leaving the land less productive and watersheds clogged with sediments. When the timber industry moved to the South in 1880, the harvesting of trees on a large scale ensued. In less than 50 years, entire ecosystems were radically changed, some to the edge of destruction. By 1920, 55 million acres had been logged, and less than half supported regeneration. Only one-third of the South's forested area remained.

The story of recovery from this low point in the history of land use in the South is often overlooked. The conservation movement helped preserve some of the remaining forest land through the creation of parks, nature preserves, and other protected areas. State forest management agencies were formed, and legislation passed that created the National Forest System in the East. The Civilian Conservation Corps (CCC) of the 1930s, and the Soil Bank program of the 1950s and early 1960s, played a large role in the regeneration of southern forests. Between 1938 and 1963, the area of forest land in the South rose by 7 million acres due in no small part to these and similar Federal efforts. In spite of past abuses of the land, and the increased pressures over the past 100 years to provide more, southern forests today are a diverse mosaic of pine plantations, hardwood stands, and mixed pine-hardwood forests.

Many of the benefits derived from southern forests today are the result of these early reforestation efforts. Total forested area, growing-stock volume, and average annual growth and removals increased rapidly between the 1930s and 1950s. Between 1953 and 1999, total hardwood growing-stock volume increased 72 percent, while softwood growing-stock volume increased 73 percent. Average annual growth and removals of growing stock also increased during this time. From 1982 to 1999, average annual removals of growing stock increased 52 percent. Throughout this period, growth exceeded removals. It is only recently that average annual removals of softwood growing stock have exceeded average annual growth.

Forest land under private ownership has been impacted the most by plantation forestry and likely will continue to be in the foreseeable future. In 1952, pine plantations occupied less than 2 million acres in the South, while natural pine existed on 72 million acres. By 1999, the 30 million acres of pine plantations in the South nearly equaled the 34 million acres of natural pine.

The increase in acres of planted pine is seen as a double-edged sword. Those opposed to plantations believe these acres to be little more than cropland—"false forests" or "biological deserts" lacking the diversity and species richness of natural stands. FIA data indicate that pine plantations caused a decrease in species richness over a 30-year period in two Southern States (Rosson 1999). Those who favor pine plantations see them as a means of regenerating harvested sites more efficiently and producing wood at faster rates than in natural stands. In 1999, pine plantations occupied only 16 percent of the South's timberland area, but these acres provided 43 percent of all softwood growth and 35 percent of all softwood removals.

Urbanization and, to a lesser extent, agriculture pose the greatest threats of further loss of forest land in the South. As urbanization and agriculture remove additional acres from the timber base, timber resource managers must strive to retain as many acres as possible in a forested condition. With each successive inventory, FIA data indicate that pine plantations play an ever-increasing role in meeting the South's increased demand for forest products. Future population increases could result in even greater expansion of pine plantations needed to replace forest land lost to other uses and to keep pace with increased demand.

Needs for Additional Research

The South's forests have changed a great deal in the past and they are changing now. SRS-FIA attempts to measure and assess these changes. It is tasked with researching, analyzing, and reporting the extent and condition of southern forests. SRS-FIA is constantly evaluating new inventory procedures and methods and implementing those that will better detect and describe change in the South's forested ecosystems. Many of these new procedures are currently being developed.

The greatest change that is currently underway involves the transition from periodic to annual surveys. Traditionally, FIA units have surveyed each State in their regions at intervals of 8 to 12 years. These periodic surveys detected changes between inventories, but the timing often was less than optimal. Up-to-date information is necessary to accurately address rising resource issues or to determine the extent of damage from catastrophic events such as hurricanes or fires. In some instances, interim surveys were needed to update older information. In addition, the breadth and depth of the analyses described in this chapter was limited due to a lack of timely FIA data covering all Southern States. To address these shortcomings, FIA is developing a system that will provide annual updates. These annual inventories will provide new information derived from measurements taken on one-fifth of the sample locations in each State, resulting in a complete inventory every 5 years.

Historically, FIA has concentrated almost exclusively on timberland and timber products. While timber remains a primary focus for FIA, other forest resources need to be better sampled to completely assess the nation's forests and rangelands. Cooperative efforts among FIA, and fish and wildlife, outdoor recreation, and wilderness SRS units, and other resource agencies at the Federal and State level are needed to identify specific data needs and to coordinate and support the collection of this additional inventory information. As an example, USDA Forest Service Forest Health Monitoring (FHM) investigates tree pests, pathogens, understory vegetation and other components and indicators of total forest ecosystem health. The FHM data collection procedures are being integrated with those of FIA to streamline methods and to measure additional biological indicators of the health of the South's forested ecosystems.

FIA and other SRS scientists and university researchers need to be more involved in designing methods and identifying variables to assess wildlife habitat, identify recreational potential, and sample a wider array of nontimber products currently being utilized from the South's forests. FIA has recently adopted a fixed-area, mapped-plot sample design making it possible to better assess the relationships between wildlife and the effects of stand edge, density, size, and age.

Perhaps the most urgent need is the development of new remote sensing technologies that provide current satellite or other imagery compatible with large-scale inventories. Photographic coverage of forest area used by FIA is often dated. Up-to-date imagery of the South's forests is critical for accurately estimating forest cover and improving the detection and assessment of disturbance.

These changes will not come without costs. New sampling procedures may complicate, or even prevent, the detection of trends. Since the 1930s, southern forest inventories have gone from surveys based on strip cruises, to fixed-area plots, to variable radius sampling, to a mapped-plot design. Much of the data in this chapter utilizes information obtained from these differing methods. With each change, the possibility for masking actual resource trends increases. However, these costs are justified where utilizing the latest methods and technology will better position FIA to meet future needs.

Acknowledgments

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Literature Cited

Birch, T.W.; Lewis, D.G.; Kaiser, H.F. 1982. The private forest landowners of the United States. Resour. Bull. WO–1. Washington, DC: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 183 p.

Birch, Thomas W. 1997. Private forest landowners of the Southern United States, 1994. Resour. Bull. NE–138. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 195 p.

Conner, Roger C.; Sheffield, Raymond M. 2001a. Forest statistics for the southern Coastal Plain of North Carolina, 1999. Resour. Bull. SRS–59. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 61 p.

Conner, Roger C.; Sheffield, Raymond M. 2001b. South Carolina's forest resources—2000 update. Resour. Bull. SRS–65. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 31 p.

Frayer, W.E.; Furnival, George M. 1998. History of forest survey sampling designs in the United States. In: Hansen, M.; Burk, T., eds. Integrated tools for natural resources inventories: Proceedings of the IUFRO conference. Gen. Tech. Rep. NC–212. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 743 p.

Frederick, Kenneth K.; Sedjo, Roger A., eds. 1991. America's renewable resources: historical trends and current challenges. Washington, DC: Resources for the Future. 296 p.

Hartsell, Andrew J.; Brown, Mark J. 2002. Forest statistics for Alabama, 2000. Resour. Bull. SRS–67. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 76 p.

Healy, Robert G. 1985. Competition for land in the American South. Washington, DC: The Conservation Foundation. 333 p.

Knight, Herbert A. 1972. Forest resources in the Southeast: survey monitors four decades of change. Southern Lumberman. 3 p.

McNab, W. Henry; Avery, Peter E., comps. 1994. Ecological subregions of the United States: section descriptions. Admin. Publ. WO–WSA–5. Washington, DC: U.S. Department of Agriculture, Forest Service. 267 p.

McWilliams, William H.; Reese, Gordon C.; Conner, Roger C. [and others]. 1997. Today's eastern forests: what have 50 years of European settlement wrought? In: Transactions of the 62nd North American wildlife and natural resources conference: finding common ground in uncommon times. Washington, DC: [Publisher unknown]: 220–235.

Rosson, James F., Jr. 1999. An analysis of the temporal dynamics in tree species diversity for major taxa of two States in the mid-South, U.S.A. Knoxville, TN: University of Tennessee. 226 p. Ph.D dissertation.

Shands, William E.; Healy, Robert G. 1977. The lands nobody wanted. Washington, DC: The Conservation Foundation. 282 p.

Smith, W. Brad; Vissage, John S.; Darr, David R.; Sheffield, Raymond M. 2001. Forest resources of the United States, 1997. Gen. Tech. Rep. NC–219. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 190 p.

Thompson, Michael T. 1997. A forested tract-size profile of South Carolina's NIPF landowners. Res. Pap. SRS–2. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 9 p.

Thompson, Michael T. 1999. A forested tract-size profile of Florida's NIPF landowners. Res. Pap. SRS–15. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 10 p.

Thompson, Michael T.; Johnson, Tony G. 1996. A forested tract-size profile of Virginia's NIPF landowners. Res. Pap. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 8 p.

U.S. Department of Agriculture, Forest Service. 1988. The South's fourth forest: alternatives for the future. For. Res. Rep. 24. Washington, DC: [Publisher unknown]. 512 p.

U.S. Department of Agriculture, Forest Service. 2000. Land areas of the National Forest System–1999. FS–383. Washington, DC: [Publisher unknown]. 115 p.

Van Hooser, D.D.; Cost, N.D.; Lund, H.G. 1992. The history of the forest survey program in the United States. In: Proceedings of the 100th IUFRO World congress. Berlin: [Publisher unknown]: 19–27.

How have biological agents including insects and disease-causing organisms influenced the overall health of the South's forests and how will they likely affect it in the future?

Chapter 17:
Impact of Pests on Forest Health

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Key Findings

■ Insects and diseases have had considerable impact on southern forests during the past century, and serious damage from native pests and nonnative invasive pests is expected to continue.

■ Generally, the more diverse and vigorous a stand, the less likely it is to suffer significant insect or disease damage. As diversity decreases or vigor declines susceptibility to catastrophic pest damage increases.

■ Longleaf pine is the least susceptible of the southern pines to most insect and disease pests currently affecting southern forests, and its restoration on former longleaf pine sites currently forested with loblolly, slash, and shortleaf pine should lessen the impact of known insect and disease pests in those areas.

■ Because of land use history and the decimation of American chestnut by the chestnut blight, oaks probably represent a larger component of the southern forests today than at any time in the past.

■ Oak decline will continue to be a forest health issue in the region especially on national forest land, which has a higher frequency of attributes that are important in oak decline etiology (old trees, low soil fertility, and shallow soils). Among national forests, the George Washington and Jefferson have the highest incidence of this disease.

■ In central Texas, oak wilt has emerged as a major disease, causing significant damage to an environmentally restricted and vulnerable resource that is primarily valued for aesthetics.

■ The southern pine beetle will play anlñcreasingly important role in the future of the South's pine forests. Catastrophic population buildups will continue to occur, especially in overstocked, old, less vigorous forests.

■ For virtually all pests, stand age and density, tree size, and species composition affect pest behavior. Forest pest impact is greater in less intensively managed forests, and on small private tracts and public landholdings than on private industrial forests.

■ Integrated pest management, which employs silvicultural methods and various mechanical, manual, biological, and chemical tools, is the most successful strategy currently available for pest management.

■ Introduced insect and disease pests have the potential to permanently alter ecosystems in the South.

■ American chestnut has been eliminated from its niche by chestnut blight, caused by an introduced fungus.

■ Dogwoods are being eliminated from their native habitats above 3,000-foot elevation by dogwood anthracnose, caused by another introduced fungus.

■ Damage by the beech bark disease (caused by a complex of introduced insects and fungi) has only just begun in the South; barring an unpredicted natural barrier or research success, it is expected to spread throughout the southern range of American beech and permanently reduce it from a codominant tree species to a deformed mid- to understory species.

■ All eastern and Carolina hemlocks, except for treated trees and geographically isolated populations, could be killed by an introduced insect, the hemlock woolly adelgid.

■ Balsam and Fraser fir are now candidate species for listing under the Endangered Species Act due to the activity of the introduced balsam woolly adelgid.

■ The gypsy moth and the fungus causing butternut canker, both introduced species, are expected to significantly increase in activity in the South during the next 30 years, permanently altering the species composition of affected southern forests.

■ Data are not available on pest management (including silvicultural manipulation and pesticide use) on private land in the South.

■ Brown-spot disease has been estimated to reduce total annual growth of southern pines by 16 million cubic feet (0.453 million cubic meters). Existing management strategies could significantly reduce this loss.

■ Extensive planting of susceptible slash and loblolly pines since the 1930s has resulted in a continuing epidemic of fusiform rust. Damage appears to have reached equilibrium. At present, fusiform rust infects at least 10 percent of the slash or loblolly pines on over 13.4 million acres (28 percent of the host type) South-wide. Use of available, genetically improved, disease resistant seedlings, and intensively managing

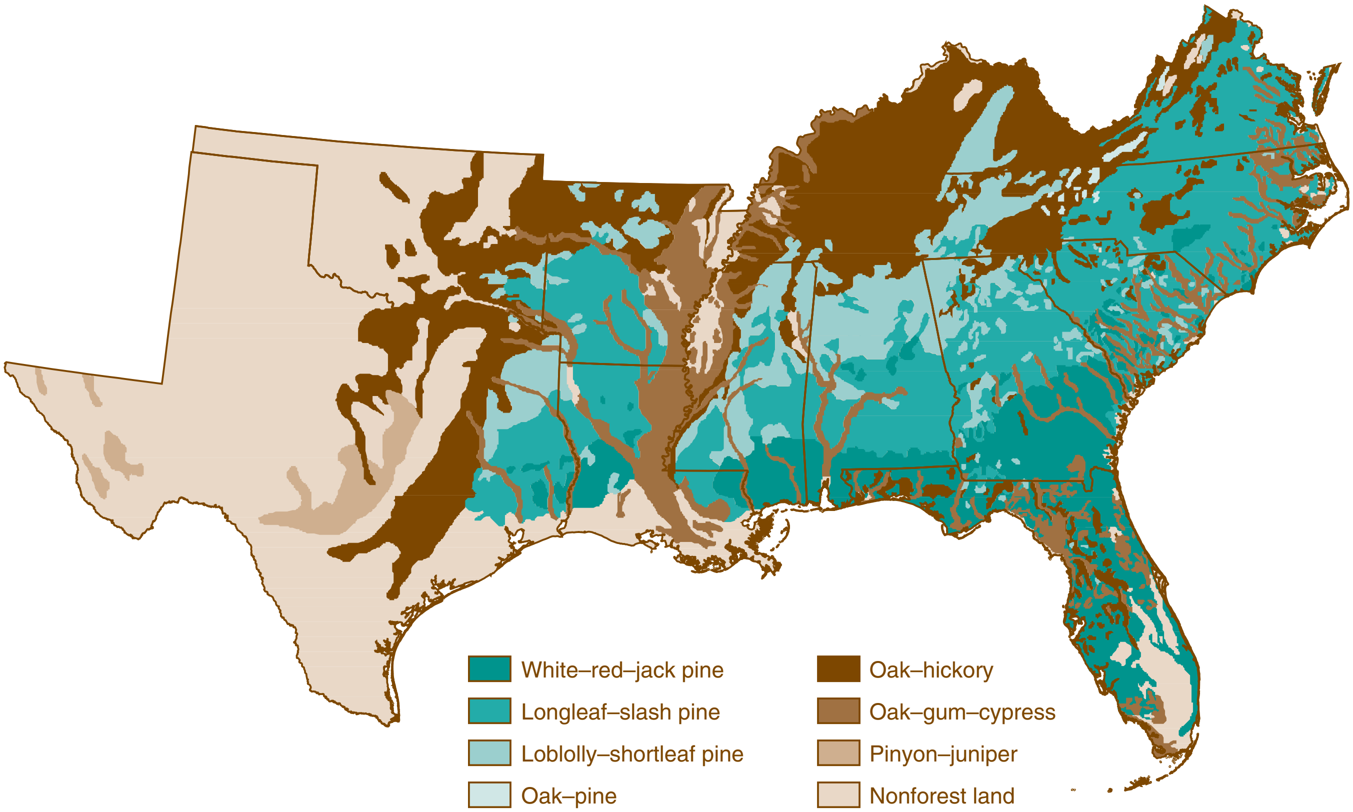

Figure 17.1—Location of major forest cover types in the Southern United States (based on Eyre 1980).

infected stands have the potential of reducing this damage.

- Concern about exportation of oak wilt to Europe has caused the European Economic Community to impose a quarantine on the importation of oak logs from United States counties where oak wilt has been documented.
- Reproduction weevils can cause 30 to 90 percent mortality in planted seedlings in the South
- Average annual losses caused by the southern pine beetle in the Southern United States exceed 100 million board feet of sawtimber plus 20 million cubic feet of smaller sized growing stock. From 1991 to 1996, total value of trees killed by the beetle in the South was estimated at $493 million. Although yet to be tried on a broad scale, prevention strategies currently available to forest managers are believed to have the potential to reduce the damage caused by this insect.
- Hardwood borers are estimated to cause more than $29 million in loss (timber value) per year. Periodic outbreaks of specific borers, such as the current epizootic of the red oak borer in northern Arkansas, cause significant damage to forest ecosystems and local economies.

Introduction

Any assessment of the region's forests would be incomplete without an evaluation of forest health. In this chapter, we provide such an evaluation for the forests of the South. We have restricted our discussion of forests to areas regenerated either naturally or through the intervention of land managers (fig. 17.1). We have excluded from our discussion specialized, small areas of forestry-related lands such as seed tree orchards or forest tree nurseries. While they are important to forestry, these areas are essentially intensively managed single species, juvenile forest stands. While no further specific mention is made of seed orchards and nurseries, it must be remembered that they are the primary production points for the genetically improved, pest-resistant plants discussed in Genetics. We have also restricted the discussion in this chapter to insect and disease pests that affect the overall health of the southern forests. Nonnative invasive plants that are major pests in the southern forest ecosystem and that have serious potential to disturb the overall health of those forests are discussed in the chapter on vegetation of the forests—chapter 2. All discussion of this extremely serious problem is found in that chapter.

"Forest health" is a concept that became popular in the 1990s and remains popular even though its precise meaning is open to debate. Often, damaging populations of forest pests are indicators of other predisposing factors such as overcrowding, over maturity, floods, drought, fire, or off-site plantings. Any analysis of the health of the forest reflects not only the well being of the ecosystem, but also the human expectations for that forest.

A healthy forest has the capacity to vigorously renew itself and to recover from a wide range of disturbances, while meeting current and future human needs for desired levels of values, uses, products, and services.

Methods and Data Sources

Information for this chapter is derived from two primary sources—published literature and the experience of the authors and their colleagues who are engaged in pest management. Experts in State and Federal agencies and in universities and other private organizations have provided information on specific pests.

A limited selection of articles is cited. Cited articles form only a small part of the extensive literature about pests of southern forests. Additional information about forest pests and their control is readily available from State and Federal forestry agencies or on the Internet (two good starting points are http://fhpr8.srs.fs.fed.us/ and http://www.na.fs.fed.us/spfo/pubs/fth_pub_pages/fidl.htm).

Results

We begin by describing pest problems in general terms and by recommending an approach to controlling pest-caused losses called integrated pest management (IPM). In this approach, pest management is viewed simply as one part of the job of managing a forest. Six common methods of pest control are described in general terms. Finally, we describe the 21 forest pests generally considered most important in the South. They are presented in four categories: native diseases, native insects, nonnative diseases, and nonnative insects.

Impact of Pests on Southern Forests

Insects and diseases can negatively impact forests in several ways. They can kill trees; reduce their growth; degrade wood and other products; cause dieback, decline and deformity; change the composition of the forest; reduce biological diversity; affect water quality and quantity; create safety hazards; increase fire risk; reduce the quality of the landscape; and cause other kinds of damage. Some of these types of damage may not be significant if they are not detrimental to the intended use of the forests.

It is important to note that pest outbreaks do not respect ownership boundaries. While the management strategies discussed below may lead to a measure of protection of forest lands from destructive insect or disease activity, failure of a landowner or land-manager to control pest outbreaks can (and often does) affect other owners lands. Passive management of forests can easily lead to pest population spillover and negatively affect forest resources of adjacent landowners.

Although impact can be expressed in many ways, it is usually measured in relation to number of trees killed, volume of timber lost, area of defoliation, or amount of growth loss resulting from pest activity. It has been estimated that forest insects account for 20 percent of the total negative growth impact on forest trees, while diseases account for 45 percent of it (Tainter and Baker 1996). Recently foresters have tried to express impact using values, such as quality of the landscape, water quality, biological diversity, and other values, that refer to the intended use of the forest ecosystem but are very difficult to assess objectively.

Native disease-causing organisms and insects are natural components of ecosystems. They often have a positive impact by contributing to biodiversity, improving habitat for various flora and fauna, and hastening decomposition and ecological succession of the forest (Coulson and Witter 1984).

Whether the effects of insects or diseases are perceived as positive or negative depends on the intended use of the forest. In a "natural" forest native insects and diseases are simply part of the ecological processes that maintain a mosaic of ages and stand conditions. Dead and dying trees contribute to the health of natural forests by contributing to the crucial processes that recycle elements from dead or downed trees. They also are among the mechanisms driving removal of the weakest and favoring the healthiest trees in any stand.

In an industrial plantation, where profit from wood is the primary objective, the presence of dead and dying trees is not generally considered a healthy condition. The more intensive the forest management, the more forest pests become potential threats for the intended use of the forest. However, with more intensive management this potential damage is generally precluded by management practices designed to forestall pest-caused damage. Impacts of insects and diseases can be even greater in urban forests, where buildings and other structures and peoples' lives are threatened by falling trees or branches.

Problems Caused by Invasive Nonnative Pests

As global trade and travel increases, so do the risks that nonnative forest pests will be introduced into the United States. They are often moved unintentionally as riders on plants, animals, personal property, or packing materials.

Nonnative insects and diseases have permanently changed southern forest ecosystems, and efforts to control them have cost hundreds of millions of dollars. Once established, populations of some imported insects and disease-causing organisms have quickly increased because natural control agents present in their native habitat were absent or ineffective in the new habitat. As a result, exotic pests have changed, and will continue to change, entire ecosystems by displacing native flora and fauna.

Early Forest Pest Control

Until the late 1940s, little was done in the South to control forest pests. They were viewed like wind, lightning, or other acts of God. It was believed that little could be done to control them.

After World War II, State and Federal agencies in the South began to recognize forest protection as a necessary part of forest management. Maximizing the production of wood and wood fiber in the South became desirable. Congress authorized funds to build the capacity to protect forests at the State and Federal levels. State forestry organizations hired forest protection specialists; and universities and colleges began to teach courses about protection of forests from fire, insects, and disease. State and Federal agencies as well as universities conducted research on forest pests. Through the 1950s, 1960s, and 1970s forest management was commodity or use driven, and some control methods used, though highly effective in generating product, were not environmentally friendly.

Emphasis was placed on chemical control, especially after the development of chlorinated hydrocarbon pesticides, such as DDT, BHC, and lindane. During this era, control of forest pests required intensive labor and, in many cases, was perceived by many people as being damaging to the environment as well as injurious to the people who applied the treatments. Rachel Carson's book, *Silent Spring*, decried the existing pattern of pesticide use, calling instead for a more intelligent use of these chemicals. The book catalyzed the environmental movement in the United States during the 1960s and 1970s. Public outcries against the use of chemicals in the forest resulted in the banning of several pesticides and challenged managers to use and researchers to develop additional environmentally friendly methods for controlling forest pests.

Integrated Pest Management

The best approach to managing pest problems is to combine prevention and control strategies to meet natural resource management objectives. This approach is called IPM.

Pest management should be a part of the overall management plan for a forest. The need for pest control can usually be minimized through wise, long-term forestry practices that promote healthy and vigorous trees. The control methods chosen will depend on the kind and amount of control necessary, the costs, and the benefits within legal, environmental, and other constraints.

The most important principle of pest control is to use a control method only when it will prevent the pest from causing more damage than is reasonable to accept. Even though a pest is present, it may not be necessary to control it. Both economics and ecology affect the decision to control or not. Exceptions are newly introduced nonnative invasive pests for which adequate data on potential spread and impact are unavailable.

The four main pest management strategies are: (1) prevention, making the forest more resistant to the invasion of pests or more resilient if attacked; (2) suppression, lowering unacceptably high pest populations to acceptable levels; (3) eradication, eliminating the pest from the ecosystem; and (4) exclusion, preventing the movement of nonnative pests into a new area. Ideally, managers will scientifically select the most effective, most environmentally friendly method (Thatcher and others 1986).

Control Methods

Silviculture—Silvicultural methods for controlling pests include practices that favor the appropriate species for the site or increase the vigor of the plants left on the site. During site preparation, thinning, or any other stand improvement activities, opportunities exist to favor the healthiest and most natural components of an ecosystem. Normally, vigorous, mixed-age and mixed-species forests are more resistant to devastation by native pests than are single-species plantations.

Genetics—Often, a portion of a population is less affected by a pest than is the remainder of the population. This ability to tolerate attack by a pest may result from inherent resistance in the population. When resistance is genetically based, favoring and propagating resistant individuals will add a measure of protection to the next generation. Breeding to enhance genetic resistance takes advantage of a natural process, augmenting it but not significantly altering it. However, as managers breed genetically resistant plants, pest populations adapt to attack the newly developed resistant host material. The process of genetic manipulation is, therefore, an ongoing process, not a permanent solution.

In recent years a new technology, genetic engineering (which involves altering the genetic structure of living organisms at the molecular level) has emerged. Pests can be engineered, altering their genes to make them less successful in reproducing or less aggressive in attacking potential host material. Alternatively, hosts can be genetically engineered to make them more resistant, or even toxic, to invading pests. Currently, little genetic engineering is being done with southern forest trees. The potential of this method is unclear because use of this method is currently very controversial. Genetic engineering is perceived by some as having the potential to accidentally kill beneficial organisms or even to create new pests.

Quarantine—State and Federal agencies often restrict the movement of live plants or animals across State or national boundaries unless they are declared free of pests. These quarantines have been fairly effective in reducing the spread of known pest organisms but have failed to stop many organisms that are not pests in their native environment but become pests when moved. As discussed elsewhere, quarantine restrictions have been ineffective in preventing the introduction of ornamental plants, which subsequently are shown to have no natural enemies in their new ecosystems. Plant quarantine to ensure the health of incoming vegetative materials and prevent the dissemination of infested or infected materials is a critical process for protecting the future health of the southern forests.

Sanitation—Sanitation involves removing infected or pest-infested materials from an ecosystem in an attempt to reduce or eliminate pest impact in response to pest outbreaks, or as a part of regularly scheduled stand maintenance activities. Affected trees or small blocks of trees are selectively removed, leaving the healthy vigorous ones. Sanitation can be highly effective if signs and/or symptoms are readily visible.

However, where symptoms are masked, large numbers of infected or infested trees may be left. Prescribed fire is often used to suppress pests either by killing them or destroying or modifying their habitats.

Chemical control—When properly applied, pesticides are very useful in suppressing or eradicating pest organisms. Pesticides used in the southern forests include insecticides, herbicides, rodenticides, and fungicides (U.S. Department of Agriculture Forest Service 1992).

Pesticides can suppress pest populations by killing the pests outright or by moderating their activity. They may be applied from the air or the ground. New pesticides have been developed that kill only the intended pest or affect a very limited number of target non-organisms. In southern forests a limited number of treatments (2 to 4) in the 40- to 120-year rotation may occur.

Despite an impressive record of success in controlling pests, and progress to improve their selectivity, pesticide use in the South has declined steadily in numbers of acres treated, as well as in rates of pesticide applied per acre. Data are not available on pesticide use on industrial and private land in the South. It is believed that the downward trend in pesticide use is not as marked on these lands as it is on national forests.

Biological control—Biological control involves the use of one organism to moderate or control the behavior of another organism. In biological control, the manager attempts to locate a natural enemy of a pest and augment its population to control unacceptable population levels of the pest. Viruses, bacteria, fungi, and insects have all been used in biological control (Stairs 1971). Apparent biocontrol of an epidemic population of gypsy moth by the fungus *Entomophaga miamiaga*, the use of a virus against sawflies, and the use of another fungus against the introduced pine sawfly are examples of successful biocontrol. Biological control, however, suffers from a problem very similar to genetic control. Often, this process has only provided short-term solutions. Natural enemies of a pest organism may fail to colonize the same niche as the pest, and either totally fail as biocontrol agents, or themselves become pests in the niche they do colonize.

Damaging Insect and Disease Agents

The following information on 21 of the most important forest pests in the Southern United States is provided by experts from universities, the private sector, and State and Federal forestry agencies.

Native Diseases of Conifers

Fusiform rust—Fusiform rust, caused by the fungus *Cronartium fusiforme* f. sp. *fusiforme*, occurs primarily on slash and loblolly pines. It is considered the most destructive disease of southern pines, causing cigar-shaped galls on the main stem that are generally fatal (Anderson and others 1980, Czabator 1971).

Extensive planting of susceptible slash and loblolly pines since the 1930s has resulted in an epidemic of fusiform rust. Infected trees can be found throughout the southern pine region (fig. 17.2), but losses are most serious on Coastal Plain sites from Louisiana to southeastern South Carolina. Several variables including weather, amount of inoculum, abundance of oaks (the alternate host), and susceptibility of the pine species govern incidence of the disease.

Nonindustrial private and industrial forest landowners own a majority of the pine host type in the South. Over 13.4 million acres Southwide have at least 10 percent of the slash and/or loblolly pines infected (Starkey and others 1997).

Control strategies designed to minimize the impacts of fusiform rust are documented in several publications. They include genetic selection, silvicultural manipulation, and chemical treatment (Anderson and others 1980, Belanger and others 1991, Dinus and Schmidt 1977, Matthews and Anderson 1979, Schmidt 1998, U.S. Department of Agriculture Forest Service 1971).

More intensively managed areas generally are at higher risk from fusiform rust. The more rapidly a tree grows, the greater its risk of becoming infected. Most practices that improve pine growth, therefore, favor rust development (Dinus and Schmidt 1977, Schmidt 1998).

The incidence and impact of fusiform rust is projected to remain stable or increase slightly in the future. A study by Starkey and others (1997) showed that there was a slight regional trend towards higher infection rates in slash pine and a slightly reduced rate for loblolly pine. In the long term, fusiform rust could be reduced by planting disease-resistant seedlings.

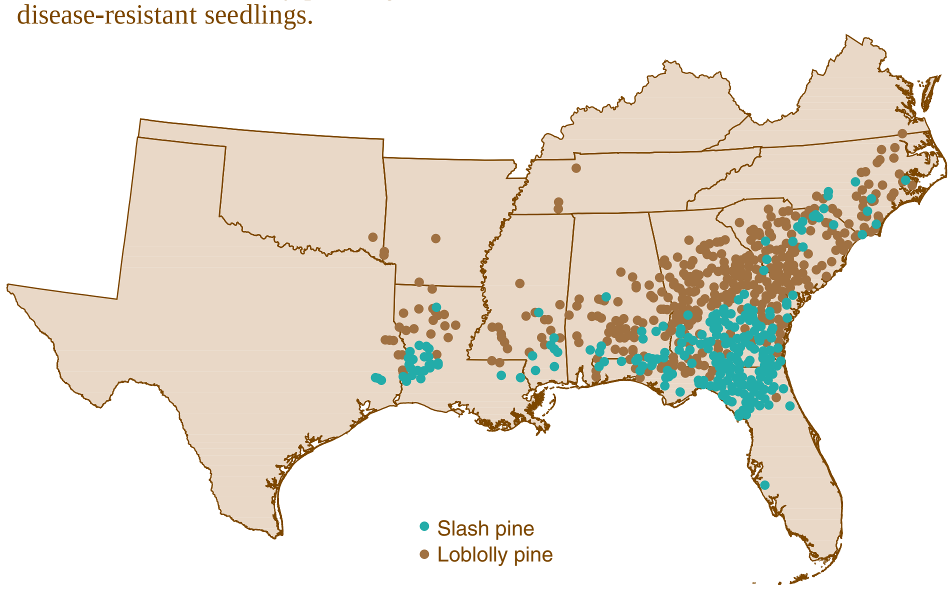

Figure 17.2—Incidence of fusiform rust on more than 10 percent of slash and loblolly pine on Forest Inventory and Analysis plots.

Annosus root disease—Annosus root disease (ARD), caused by the fungus *Heterobasidion annosum*, produces significant losses of conifers across the South. On sandy, well-drained sites, this disease causes growth loss or kills trees. It is most often associated with thinning of loblolly, longleaf, shortleaf, slash, and white pine plantations. Slash and loblolly pines are the most commonly planted species in the South and are both very susceptible to ARD (Robbins 1984, Stambaugh 1989).

A survey of ARD in the South documented 2 to 3 percent mortality and a 44 to 60 percent rate of disease occurrence in planted pine. Documented rates of radial and height growth are significantly less for diseased than for healthy pines (Applegate 1971, Froelich and others 1977, Morris 1970). The fungus enters a stand by infecting freshly cut pine stumps. It progresses into roots, and, thereafter, it grows from tree-to-tree via root contacts and grafts. First entry into a stand can be prevented by treating susceptible new stumps with borax.

The primary risk factors associated with ARD are the amount of host type available, the timing and degree of management activity, and the soil and site conditions. Risk of damage caused by ARD decreases as clay content in the surface layer of soil increases, giving us an effective risk mapping tool (fig. 17.3). In the Southeast, risk of ARD is high or moderately high on an estimated 163.5 million acres, not all currently forested (Hoffard and others 1995). Silvicultural and chemical controls can be used to minimize the impact of ARD on high-risk sites. A biological control that appears to be effective does not have EPA registration and is currently unavailable to managers.

Private industry generally favors intensive plantation management of loblolly and slash pine on short rotations of 30 to 35 years. Severity of ARD in this type of management is directly related to the number of thinnings in the stand and the proportion of sand in the soil. Industrial owners are more likely to use a full range of management options. Short rotations and intensive management generally result in low ARD caused mortality on industry lands.

On managed public land, the current trend is to restrict the amount of intensive plantation management in favor of longer rotations for watershed protection and recreation. Restoration of longleaf pine is being promoted. Of the southern pines, longleaf is considered the least susceptible to root disease, and its restoration on sites currently occupied with other pines will lessen the impact of ARD.

When pine stands managed on longer rotations have few intermediate cuts, the risk of ARD development is generally reduced. However, strategies that promote uneven-aged management with frequent cuts will likely increase incidence and severity of ARD. Management for red-cockaded woodpecker habitat, which requires frequent mid-rotation thinnings, may also increase ARD on high-risk sites (Cram 1994).

On public reserved land, where management activities are minimal, ARD will have little impact.

Private nonindustrial land, which includes 69 percent of the South's forest lands, is managed in a variety of ways, creating a range of risk for ARD. The Conservation Reserve Program (CRP), which has assisted private landowners to reforest thousands of acres of erodable cropland, has resulted in increased risk for ARD in the plantations it supports by favoring early thinning. Approximately 400,000 of the 2 million acres enrolled are on high-risk soils for ARD development (Anderson and Mistretta 1982).

Brown spot needle disease of longleaf pine—Brown spot needle disease, caused by the fungus *Scirrhia acicola*, is considered the most serious disease of longleaf pine. It causes seedlings to remain in the grass stage (an early growth stage of longleaf in which the seedling looks like a clump of grass) for an abnormally long time, delaying initiation of height growth and causing loss of potential wood production. Severely infected trees often die. Young longleaf trees become more resistant to this disease once they grow out of the grass stage.

This disease occurs from Virginia to Texas, primarily on the Atlantic and Gulf Coastal Plains. It is more severe in certain geographic areas (fig. 17.4). It has been estimated to reduce total annual growth of southern pine timber by 16 million cubic feet (0.453 million cubic meters).

At present, longleaf pine occupies only about 5 million acres of its former 60 million acre range. Difficulties in storing and handling longleaf pine seedlings have discouraged managers from planting this species.

Recent work has led to the production of healthier seedlings for planting; planting success has improved on sites where, historically, longleaf was the dominant species (Cordell and others 1989, Kais 1989). Several possible treatments are available for managers to limit the impact of this disease on their

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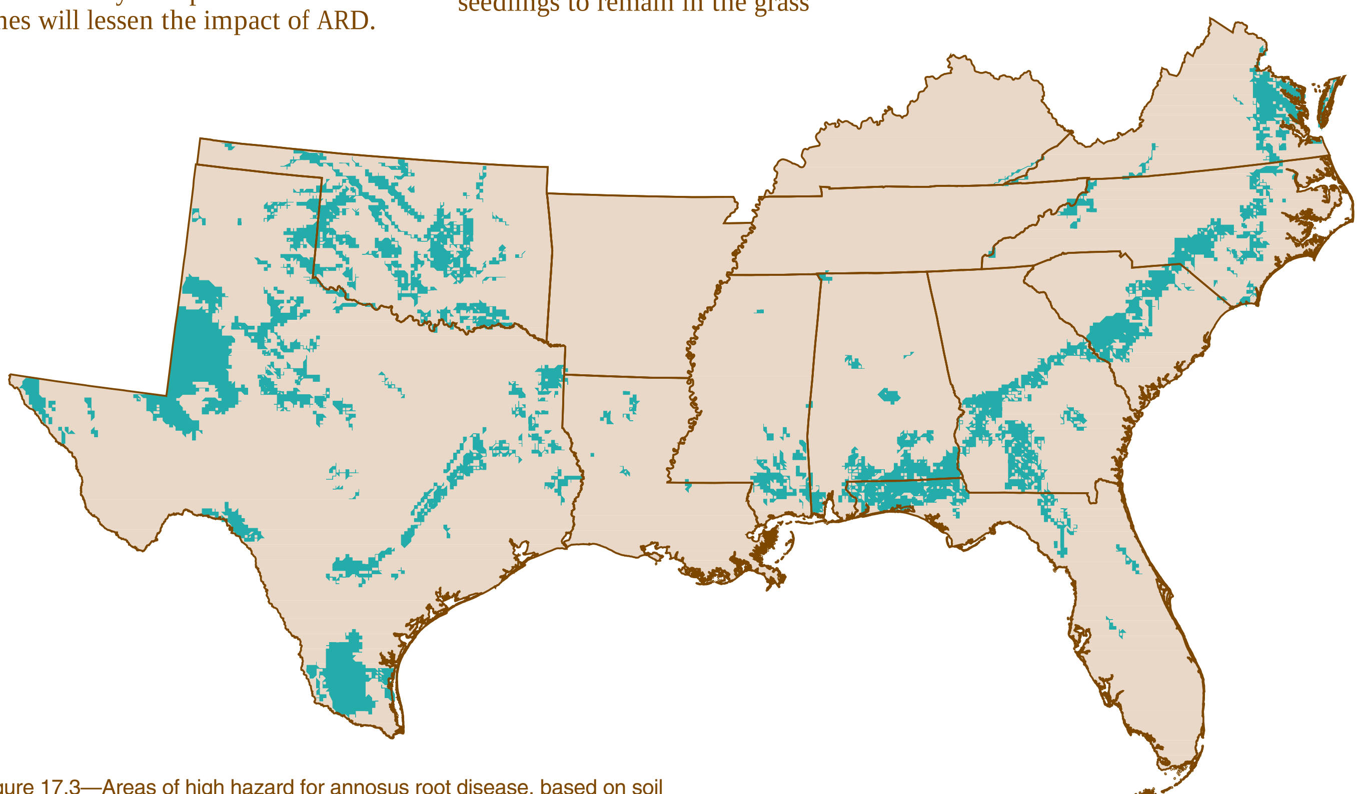

Figure 17.3—Areas of high hazard for annosus root disease, based on soil characteristics (U.S. Department of Agriculture, Forest Service 1999).

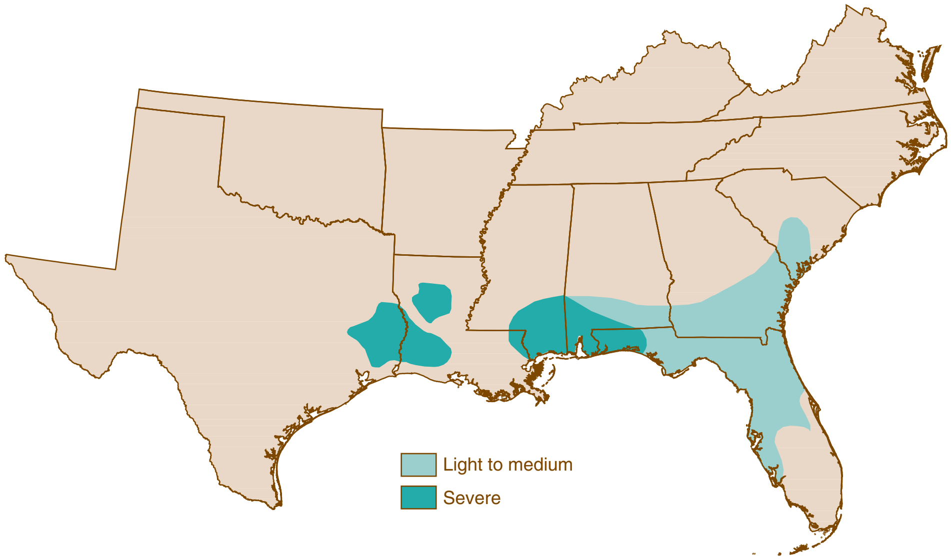

Figure 17.4—Brown spot disease range (U.S. Department of Agriculture, Forest Service 1999).

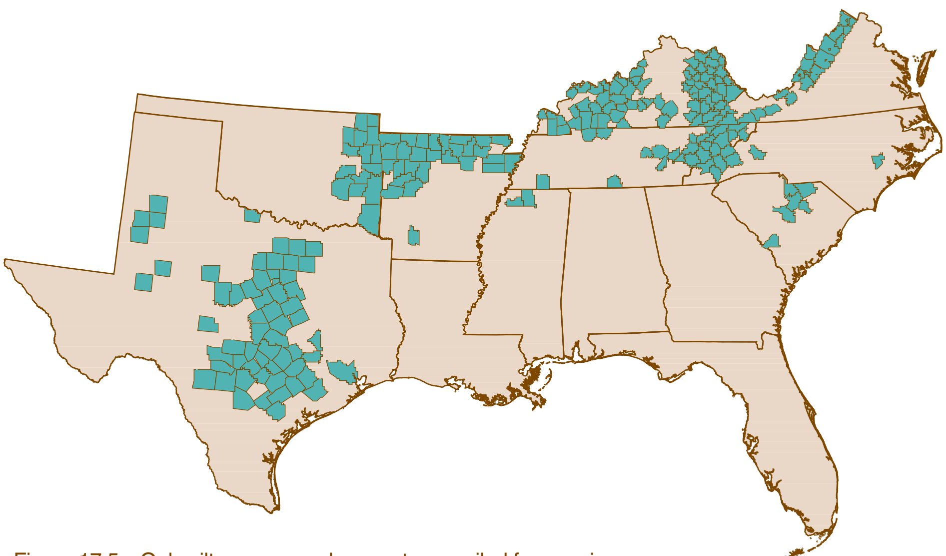

Figure 17.5—Oak wilt occurrence by county compiled from various State and other survey reports (U.S. Department of Agriculture, Forest Service 1999).

grass-stage longleaf pine seedlings. They include silvicultural, fire, and fungicidal options.

Chemical treatment of seedlings and prescribed burning are most likely to be used by managers of private industry land and managed public land. State forestry agencies are having success assisting private nonindustrial landowners in controlling brown spot; but there are a huge number of landowners to contact, and this effort is very slow.

It is expected that disease incidence will increase as attempts are made to return longleaf to its native range.

Native Diseases of Hardwoods

Oak wilt—Oak wilt is a vascular wilt disease of oaks that currently is found only in North America. The causal fungus (*Ceratocystis fagacearum*) was first identified in Wisconsin in 1942, but scientists believe the disease is native to North America and was present long before its discovery (MacDonald 1995, Tainter and Baker 1996). Oak wilt is known to occur in 21 States in the Central and Eastern United States (Rexrode and Brown 1983); 9 of the 13 Southern States are known to harbor the disease, but severe mortality is occurring only in central Texas (fig. 17.5).

Oak wilt causes affected trees to wilt and usually to die. All species of oak are susceptible, but species in the red oak group (northern red, scarlet, and black oak) are most readily killed. Oaks in the white oak group (white, post, and chestnut oaks) are infected but mortality occurs much less frequently and more slowly. Live oaks die at a rate generally intermediate between red and white oaks.

Infection centers develop when the fungus spreads to adjacent, susceptible trees via root grafts. Sap feeding beetles can carry spores to nearby healthy trees. Control strategies consist of cutting or killing infected trees and others nearby to prevent tree-to-tree spread (MacDonald 1995, Rexrode and Brown 1983, Tainter and Baker 1996).

Oak wilt control programs were implemented in a number of Eastern States in the 1960s and 1970s, but devastation of oaks never developed as originally feared. Evaluations of control programs seem to indicate that efforts had little effect on the number of infection centers or the number of oaks that died, and most control programs have been discontinued.

In central Texas, however, catastrophic losses, primarily in live oaks with lesser loss of Texas red oak, have generated much interest and concern since the 1980s (Appel and Billings 1995). Oaks in this area have little commercial value, but they are highly prized for shade, aesthetics, wildlife, and their contribution to watershed health. Both rural and urban trees are affected. An active control program has been in operation since 1988 (Cameron and Billings 1995). Control treatments successfully implemented in central Texas include trenching to sever root connections and fungicide injections to prevent mortality of individual, high-value trees.

Concern over the importation of oak wilt to Europe has resulted in an import quarantine being imposed by the European Economic Community countries on oak logs from United States counties where oak wilt has been documented. Oak logs exported from such counties must be fumigated and then be certified disease free.

Oak wilt will continue to affect the oak resource in its current range. Of greater concern is the possibility that the oak wilt fungus, having adapted to Texas oaks and their environment, may now spread throughout the southern range of oak.

Oak decline—Because of the history of woods grazing, widespread wildfire, exploitive logging for wood products, and the loss of American chestnut to chestnut blight, oaks probably represent a larger component of the southern forest ecosystem today than at any time in the past (Millers and others 1990).

Oak decline in upland hardwood and mixed oak-pine forests is a disease complex involving environmental stressors, often drought, root diseases such as are caused by *Armillaria* spp., insect pests of opportunity such as the two-lined chestnut borer, introduced pests such as the Japanese beetle and Asiatic oak weevil, and physiological maturity of the trees (Staley 1965, Wargo 1977, Wargo and others 1983). Bottomland oak forests are also subject to oak decline but at a lower incidence. Stress agents of bottomland hardwoods also include seasonal, sometimes prolonged flooding.

Decline progression is measured in decades rather than months or years. Introduction of the gypsy moth into northern parts of the region has worsened oak decline because oaks are preferred hosts, and spring defoliation contributes to the chain of events that increase susceptibility. While decline development may take decades from inception to visible symptom expression, susceptible trees die within a few years after dieback exceeds one-third of the crown volume. Not all affected trees reach this point. Species in the red oak group (particularly black and scarlet oaks) are most susceptible. Hickories are the only non-oak species group commonly observed with symptoms in decline areas (Starkey and others 1989).

Forest workers have reported oak decline occurrences since the mid-1800s (Balch 1927, Beal 1926) and in every decade since the 1950s (Millers and others 1990). A severe drought in the 1950s may have led to the current cohort of trees being highly susceptible to oak decline (Dwyer and others 1995, Tainter and others 1990). Significant oak decline episodes continue to occur in the region (primarily in Arkansas and Virginia) where predisposing conditions, inciting events, and contributing factors are coincident (Starkey and others 2000).

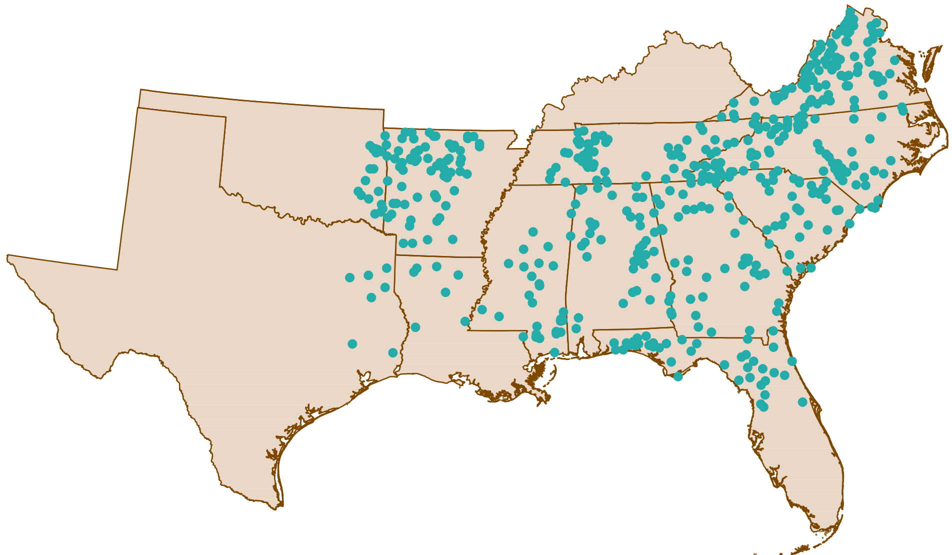

Figure 17.6—Forest Inventory and Analysis plots affected with oak decline (U.S. Department of Agriculture, Forest Service 1999).

Not all oak forests are equally affected (fig. 17.6); Virginia, North Carolina, and Tennessee have the highest incidence. Among physiographic subregions, the Southern Appalachian and Ozark-Ouachita Mountains are most affected. Species in the red oak group suffer greater impacts than those in the white oak group (Gysel 1957, Oak and others 1988).

Although most of the decline-affected area is on privately owned land, national forests have by far the highest incidence of this problem because they have a higher frequency of stands with the attributes that favor this disease (older aged oaks predominate, oak species composition favoring susceptible species, and average to low site productivity) (Oak and others 1991, 1996). Among national forests, the George Washington and Jefferson have the highest incidence of oak decline.

The relative importance of oak is both a biological and a social question, but the cumulative impacts of the loss of American chestnut, continued oak decline, and ongoing defoliation by the gypsy moth indicate that special efforts must be made if the oaks are to maintain their prominence in the forest. Risk rating models have been developed to aid in this process (Oak and Courter 2000, Oak and Croll 1995, Oak and others 1996).

Oak decline will continue to be a forest health problem, particularly on national forest land. Oaks will not be eliminated from affected areas, but their numbers and diversity will be reduced. Red maple, blackgum, and other relatively shade tolerant species are likely to replace the oaks. As this change occurs, forest structure becomes more complex, the quantity of standing trees and woody debris increases, and overall susceptibility to oak decline and gypsy moth is reduced.

Subsequent decline in hard mast production is another serious impact of this problem.

Native Insect Pests of Conifers

Southern pine beetle—The southern pine beetle (SPB) (*Dendroctonus frontalis*) is the most destructive insect pest of pine forests in the South (Thatcher and Conner 1985). Populations build rapidly during periodic outbreaks and kill large numbers of trees. Average annual losses may exceed 100 million board feet of sawtimber and 20 million cubic feet of growing stock. From 1991 to 1996, total value of trees killed by SPB in the Southern United States was estimated at $493 million (Price and others 1998). However, during endemic periods, SPB populations may be so low that it is difficult to locate a single infested tree or capture beetles in pheromone traps (Thatcher and Barry 1982, Thatcher and others 1980).

The SPB, which attacks all species of pines, prefers loblolly, shortleaf, Virginia, pond, and pitch pines but

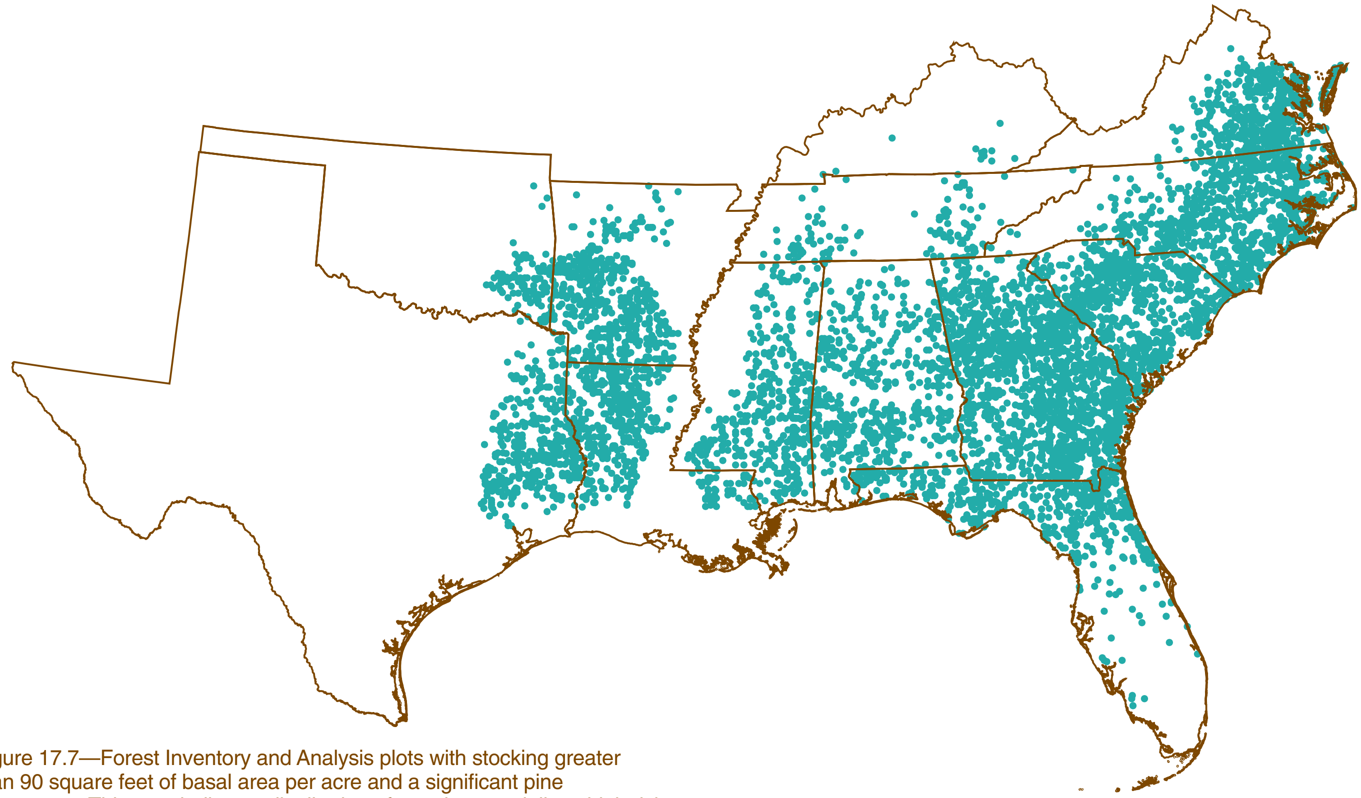

Figure 17.7—Forest Inventory and Analysis plots with stocking greater than 90 square feet of basal area per acre and a significant pine component. This map indicates distribution of stands potentially at high risk of attack by southern pine beetle.

seldom attacks longleaf pine. Recently, SPB has been observed to successfully infest white and Table Mountain pines. Mature trees in pure, dense stands have long been considered most susceptible to SPB attack (fig. 17.7), but in recent years unthinned pine plantations have increasingly supported SPB infestations. Trees less than 5 years old or 2 inches in diameter are seldom attacked.

During outbreaks, SPB activity peaks in early summer in the Gulf States and in late summer and early fall farther north.

Figure 17.8 shows a summary of SPB outbreaks as reported by Price and others (1998). Since 1960, a SPB outbreak has occurred somewhere in the South almost every year. Outbreaks, which may last 3 to 6 years, have been most severe and persistent in southeast Texas and southwest Louisiana, central Mississippi, the Piedmont of Alabama, Georgia, and South Carolina, and the Coastal Plain of Georgia, and North and South Carolina. Currently a catastrophic infestation of SPB is threatening pines in Virginia, Kentucky, Tennessee, North Carolina, and Georgia. Ridgetop pine ecosystems for which control options are extremely limited are of special concern to ecologists and forest managers.

Natural enemies, including diseases, parasites, and predators, can help maintain beetle populations at low levels. However, they seem to have little effect in preventing periodic outbreaks.

The primary suppression method is to salvage infested trees plus a buffer of green trees to stop spot expansion. Cutting and leaving infested trees, under appropriate conditions, also protects the residual stand (Swain and Remion 1981).

While chemical treatments are available, chemical insecticides are seldom used on a large scale to suppress SPB. They are most often used to prevent attacks of SPB and associated bark beetles on individual

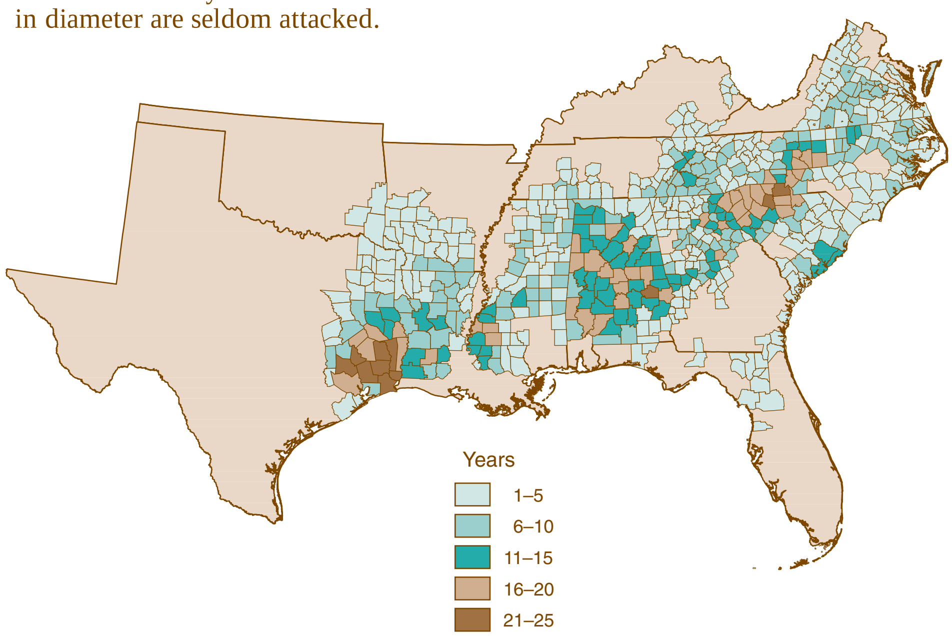

Figure 17.8—Counties in outbreak status for southern pine beetle; a 40-year summary (U.S. Department of Agriculture, Forest Service 1999).

trees of high value. A new semiochemical is being tested to protect trees from SPB attack.

The most practical way to minimize timber losses and avoid costly, short-term suppression projects is to maintain forests in a vigorous, healthy condition. Several practical hazard-rating systems have been developed to help managers to prioritize SPB prevention activities. Thinning and harvesting are extremely important prevention tools since outbreaks are generally less likely in actively managed forests, where management is designed to enhance health and vigor of the residual stand.

SPB outbreaks affect pine forests on all ownerships. The severity of loss tends to be greatest on Federal forests due to the preponderance of mature pine sawtimber in dense stands. Areas set aside for wilderness or preserves have proven especially prone to SPB outbreaks, due largely to the advanced age, high density of the stands, and the policy of not controlling SPB on these areas.

In the last five decades, large acreages of pine plantations have been established in the South. Even-aged, single-species plantations become increasingly susceptible to SPB infestations as they age. Precommercial and commercial thinning to promote rapid growth in these plantations should reduce their susceptibility to future SPB outbreaks. Nevertheless, the SPB is expected to play an increasingly important role in the future of the South's pine forests.

Impacts vary with ownership. Federal land supporting an abundance of overmature loblolly pine forests is expected to be particularly vulnerable to extensive outbreaks. Industrial forests are likely to suffer SPB problems primarily in young, unthinned pine plantations. Short-rotation pine plantations receiving intensive management (periodic thinning, fertilization, etc.) should have minimal problems with SPB. Small private forests will face SPB problems in inverse proportion to management intensity.

SPB will continue to play a major role in the health of the southern forest. Catastrophic population buildup will continue to occur periodically. When this occurs survivor species will assume a higher profile in the residual forest. In some cases, total loss of the pine component in the forest may result.

Bark beetles other than southern pine beetle—Although the southern pine beetle is the most damaging insect in southern pine forests, it is only one of five species of pine bark beetles of concern for forest managers in the South. The other species are the six-spined engraver (*Ips calligraphus*), the southern pine engraver (*Ips grandicollis*), the small southern pine engraver (*Ips avulsus*), and the black turpentine beetle (BTB) (*Dendroctonus terebrans*). These beetles are usually considered secondary pests because they normally infest only stressed, weakened, damaged, or downed pines. They also colonize pines that have been attacked by SPB or another species of bark beetle. Host species in the South include loblolly, shortleaf, slash, longleaf, pitch, sand, eastern white, and Virginia pines. Both pure pine and mixed pine-hardwood stands may be affected (Conner and Wilkinson 1983, Smith 1972, U.S. Department of Agriculture Forest Service 1985a).

Adult BTBs are the largest of the southern pine bark beetles. Although BTB attacks may continue for several months, infestation is not always fatal, and multiple attacks around the entire circumference of the tree are required to cause mortality (Smith 1972, U.S. Department of Agriculture Forest Service 1985a).

The small southern pine engraver is the smallest of the *Ips* spp. in the South; the southern pine engraver is midsize; and the six-spined engraver is the largest. The small southern pine engraver and the six-spined engraver are the most aggressive and may kill small groups of trees. Losses may be extensive during periods of drought (Conner and Wilkinson 1983, U.S. Department of Agriculture Forest Service 1985a).

In the past, the secondary bark beetles played a vital role in shaping forest structure. They attacked individual weakened or severely stressed trees, or older trees reaching senescence. Large infestations developed only occasionally, usually in the aftermath of widespread environmental stress, drought, storm damage, or wildfire. Overall, their action served to thin the pine forests, reducing competition, leaving the stronger trees, and decreasing the risk of SPB outbreaks. Over time, they may have had a greater impact on regulating pine stands than SPB (Clarke and others, in press; Paine and others 1981; Thatcher 1960a).

Today, the impact of these other bark beetles depends largely on management activities (Coulson and others 1986). On unmanaged land they function much as they did in the past, attacking single trees or small groups of pines, and reducing pine basal area. They provide openings for pine reproduction or for established hardwoods to grow. The effects are often not noticeable except during periods of extended drought, after storm damage, or at the end of SPB epidemics.

On managed land, outbreaks of secondary bark beetles occur infrequently, and primarily impact dense, unthinned young pine stands. Infestations temporarily increase after burning or thinning. Increases in beetle activity are usually short-lived, and the long-term benefits of thinning and prescribed burning outweigh the temporary, negative effects. Black turpentine beetles may attack pines scored for the production of naval stores. *Ips* bark beetles quickly infest pines downed by storms, and often introduce blue stain fungi that invade the wood.

Secondary bark beetles are important killers of individual, high-value pines in urban or recreation areas. There they create hazard trees that are expensive to remove.

In the past, secondary bark beetle infestations were often aggressively controlled, usually by felling and then spraying the affected trees with insecticides. This tactic was expensive and killed the natural enemies of the beetles. It was determined that such treatments were generally not cost effective, and today few infestations are controlled. When large infestations develop after drought or wildfire, prompt salvage of the currently infested trees may limit the spread of the beetles and allow time for uninfested, stressed trees to recover. Populations of secondary bark beetles infesting storm- or fire-damaged pines rarely move into healthy trees.

Prevention is the key to reducing losses to secondary bark beetles. Maintaining healthy pine stands and minimizing damage during management activities keep impacts low. If infested trees in high-value areas cannot be removed, the at-risk pines may be sprayed with insecticides to prevent attacks. Only the lower bole should be sprayed for BTB, but the entire bole must be treated to keep out *Ips* bark beetles.

Secondary bark beetle activity and damage are expected to continue at natural levels into the future. Periodic significant outbreaks will also continue to occur.

Pine reproduction weevils—The pales weevil (*Hylobius pales*) and pitch-eating weevil (*Pachylobius picivorus*) are two of the most serious insect pests of pine seedlings in the Eastern United States. In the South, they are found wherever pine occurs (fig. 17.1). Adult weevils of both species are attracted to freshly harvested pines, where they breed in logging slash, stumps, and old root systems. Seedlings planted in freshly cut areas are injured or killed by adult weevils that feed on bark. It is common to have 30 to 60 percent weevil-caused mortality among first-year seedlings in the South, and mortality of 90 percent or more has been recorded (Thatcher 1960b). A third species, the eastern pine weevil is generally less common but is known to kill terminal and lateral branches and to girdle the stems of small trees (Doggett and others 1977, Nord and others 1984).

In the South, pales weevils prefer loblolly, shortleaf, pitch, and white pines and almost never attack longleaf pine. Rare instances of pales weevil feeding on hardwoods also have been recorded. The pitch-eating weevil is reported to feed on similar hosts, whereas the eastern pine weevil prefers cedar but will also attack most southern yellow pines. Pales and eastern pine weevils may serve as vectors of various pathogenic fungi.

In the South, weevil control is unnecessary after winter or spring cuts because all weevils are gone before the next winter's planting. On the other hand, after summer or fall cuts, control will probably be necessary because the weevils remain onsite and attack newly planted seedlings during the spring (Corneil and Wilson 1980, Grosman and others 1999, Speers 1974). Weevils are not a problem when plantations are established on areas formerly covered with nonconiferous vegetation (for example, old fields and hardwoods) or on land where stands are allowed to regenerate naturally.

Only a few biological control agents that affect reproduction weevils have been reported. Very little is known about their effect in regulating field populations. Silvicultural and chemical strategies are available to reduce losses to reproduction weevils. A hazard rating system is available and should be used before scheduling pine planting.

Forest managers who harvest, prepare the site, and plant on a schedule that allows stumps to stale after cutting and prior to planting do not often experience high weevil-caused seedling mortality. In contrast, nonindustrial private landowners who often plant during the spring after late-year harvests often experience greater than 20 percent weevil-caused seedling mortality (Grosman and others 1999).

Reproduction weevil impacts may increase in the future. Current trends suggest that forest industry will continue to shorten rotations and may be less willing in the future to delay replanting to avoid the weevils. This trend could lead to an increased risk of weevil-caused damage or an increased need for proactive control strategies. Informed land managers can effectively reduce or eliminate the risk of weevil-caused damage, so education is a key to future prevention of this problem.

Nantucket pine tip moth—The Nantucket pine tip moth (*Rhyacionia frustrana*) is one of the most common forest insects in the Southeast (Berisford 1988). Although it is usually considered a southern pest, its range includes most of the eastern half of the United States.

Most hard pines are susceptible to attack by the Nantucket pine tip moth, but there are considerable differences in relative susceptibility. Among the southern pines, shortleaf, loblolly, and Virginia pine are highly susceptible, while slash and longleaf pine (with the exception of very young nursery seedlings) are highly resistant.

Damage, while potentially serious, is normally transitory or negligible in forest stands. Tip moth damage (loss of growth and deformation) is most severe on seedlings and saplings, usually under 5 years old. Deformation is particularly important on ornamentals and Christmas trees, which may become virtually worthless if tip moth attacks are not controlled. Experts disagree about the long-term impact of Nantucket pine tip moth attacks.

The abundance of the Nantucket pine tip moth is strongly affected by the availability of preferred hosts that are in susceptible age classes. Colonization of pine plantations is often rapid (Clarke 1982). Highest tip moth populations and damage tend to occur in even-aged, low-diversity stands (Berisford and Kulman 1967). Intensive stand management techniques including mechanical site preparation, or the application of herbicides or fertilizer, increase tree growth, but often favor increased tip moth damage (Nowak and Berisford 2000). The primary effect of ownership on this disease is a secondary effect of choice of management intensity. Naturally regenerated stands or plantations that are not managed intensively generally do not suffer enough damage to offset the cost of control.

Reliable sampling methods have been developed for determination of tip moth populations. However, the necessary links between population estimates and damage predictions have not been established.

The biology of the Nantucket pine tip moth as it relates to control is described in a variety of publications (Berisford 1974, Fettig and Berisford 1999, Haugen and Stephen 1983). Nantucket pine tip moth has a significant complement of natural biocontrol agents (Eikenbary and Fox 1965, 1968; Warren 1985). While several are being evaluated for use, none are commercially available. Insecticidal control can be used if damage is severe. There are a number of insecticides registered for tip moth control and for aerial application.

Tip moth infestations in loblolly pine stands are generally regarded as inevitable. However, as the acreage of intensively managed pine plantations is predicted to increase, this tip moth should become a more common pest problem in the future.

Baldcypress leafroller (formerly fruittree leafroller)—The baldcypress leafroller, *Archips goyerana*, periodically defoliates baldcypress in Louisiana. It has also recently been found in Mississippi. Kruse's publication (2000) describes the baldcypress leafroller, summarizes its biology and its effects on baldcypress, and lists relevant publications.

The baldcypress leafroller was first recorded in 1983 in Louisiana, where it feeds almost exclusively on baldcypress. Since 1983, it annually has defoliated the baldcypress component of the bottomland hardwood/cypress forest (about 35,000 acres).

While this insect is mainly a pest of flooded baldcypress, it can move into drier upland and urban settings during periods of heavy infestation. Baldcypress trees of all sizes display canopy dieback and significant reductions in diameter growth because of repeated annual defoliation. Pole-sized to small sawtimber-sized baldcypress trees growing on forest edges or in dense stands are most severely affected. In areas where chronic saltwater intrusion is a problem, trees die after as little as 2 consecutive years of defoliation.

Most defoliation caused by baldcypress leafroller occurs on unmanaged private, nonindustrial wetlands. Although several parasitoids and predators attack *A. goyerana*, the general lack of natural enemies in forested wetlands leads to persistent high populations of this leafroller. Lacking economic incentives, little or no direct control is applied. A bacterial spray is available, but is seldom used. Starvation is the major factor causing local reductions in caterpillar populations. One potential future control tactic involves planting genotypes of baldcypress, cultured originally for salt tolerance, which may minimize caterpillar development and limit female fecundity.

High populations of *A. goyerana* are expected to continue in the forested wetlands of southern Louisiana and Mississippi. The insect may spread and become a problem in other areas of the Gulf Coast, but movement has been slowed by breaks in the baldcypress forest type (mapped as oak-gum-cypress) and the obstacles presented by large bodies of water. Dieback and mortality of baldcypress trees will increase.

Texas leaf-cutting ant—The Texas leaf-cutting ant, *Atta texana*, is a serious pest in first- and second-year pine plantations in east Texas and west-central Louisiana. In areas where the ants are abundant, it is nearly impossible to establish pine plantations. Pine seedling mortality due to the Texas leaf-cutting ant occurs on nearly 12,000 acres annually and control and seedling replacement costs average $2.3 million per year (Cherret 1986, Texas Forest Service 1982).

The Texas leaf-cutting ant is generally confined to well-drained, deep sandy soils (Moser 1984, Vilela 1986). Figure 17.9 shows the range of the Texas leaf-cutting ant in Texas and Louisiana.

The impact of this insect appears to be unaffected by management intensity or ownership (Waller 1986).

Currently, only one chemical is registered to control Texas leaf-cutting ants, and it is scheduled for phase-out by the year 2005. A new baited formulation containing a slow-acting insecticide has been highly effective in field trials but is not yet registered for use.

Untreated colonies will remain a source of reinfestation and future losses.

Native Insect Pests of Hardwoods

Forest tent caterpillar—The forest tent caterpillar (FTC) (*Malacosoma disstria*) occurs throughout most of the United States and Canada, where it defoliates a variety of hardwoods (Batzer and Morris 1978, Fitzgerald 1995, U.S. Department of Agriculture Forest Service 1985b). In the South, it heavily defoliates water tupelo, sweetgum, blackgum, and various oak species. The most persistent and extreme outbreaks in the South occur in bottomlands, forested wetlands, and riparian areas. However, when FTC populations reach epidemic levels, the caterpillars often spread to urban and suburban areas where they defoliate a variety of shade trees and ornamental plants. Outbreaks in recreation areas may adversely affect business due to the nuisance created by migrating caterpillars and the presence of completely defoliated trees during the tourist season.

Outbreaks of the FTC occur in several Southern States, where well over 500,000 acres can be defoliated in a single season; FTC defoliation does not cause significant amounts of tree mortality. However, it does cause significant loss of tree growth. Repeated, heavy defoliation of stands may cause significant amounts of dieback.

Impacts of FTC occur mainly in the bottomland hardwood-cypress forest types (mapped as oak-gum-cypress and elm-ash-cottonwood), but they are occasionally a problem in upland northern hardwood forest types (mapped as maple-beech-birch, oak-hickory, and oak-pine). Most FTC defoliation occurs on forest lands that are not managed. Neither ownership nor intensity of management influences the impact of this pest. However, a number of chemical and biological treatments are available (Harper and Abrahamson 1979).

Future impacts of FTC on southern forests are likely to be much the same as in the past.

Hardwood borers—Insect borers are important pests of hardwood trees throughout the South. They tunnel in the bark, trunks, terminals, and roots,

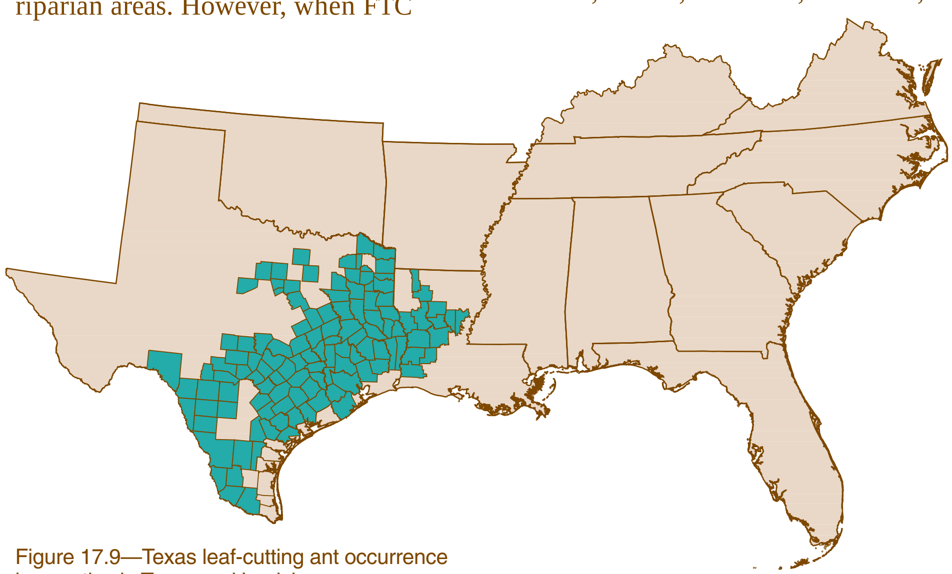

Figure 17.9—Texas leaf-cutting ant occurrence in counties in Texas and Louisiana.

causing a variety of defects in wood, deformation of stems, reduction of seed production, and tree decline.

Some of the major damaging borers in the South are the carpenterworm, red oak borer, white oak borer, ash borer, poplar borer, oak timberworm, Columbian timber beetle, and ambrosia beetle (Solomon 1995). Borers, endemic to an area, do not normally cause dieback and mortality, but in abnormally large numbers they do contribute to tree decline. Severely affected stands can be seriously degraded. Excessive numbers of growth defects caused by borers are reported to affect between 25 and 88 percent of all hardwood logs. The most recent loss estimate available (based on timber values) is slightly more than $29 million in 1998.

Prevention and control of borers in living trees are difficult and often are not economically feasible. Nevertheless, there are several options available to managers. Chemical control of woodborers is feasible only for high-value trees. Synthetic sex pheromones, available for some borer species, are useful to survey and monitor borer populations, and to establish optimum timing for insecticide application. Silvicultural treatments and practices that favor good tree health, while slow to take effect, are the most enduring controls (Graham 1959). Silvicultural controls are based on the fact that intensively managed hardwood stands on productive sites generally sustain less borer damage than those with little or no management. Ownership, except as it may affect intensity of management, has no direct effect on the activity of borers.

Recently, prolonged droughts have caused a decline in the vigor of oaks across the northern portion of Arkansas. This decline has permitted the development of a massive red oak borer outbreak. While not the primary cause of the oak mortality being experienced in that area, the borers have proven to be the most destructive agent to date in the decline complex. They have reduced salvage value to virtually nothing due to the extensive damage they have caused to the wood of dead and dying trees.

Most of the major insect borers are endemic across the South and will continue to impact hardwood stands in the future. Atypically high populations of woodborers will continue to occur periodically.

Nonnative Diseases of Conifers

Littleleaf disease—Littleleaf disease is the most serious disease of shortleaf pine in the Southeast. It is caused by a complex of factors including a nonnative fungus, *Phytophthora cinnamomi*, low soil nitrogen, eroded soils, a plow pan (from farming), and poor internal soil drainage (Campbell and Copeland 1954). Often, native microscopic roundworms called nematodes and native species of the fungal genus *Pythium* are associated with the disease. Infected trees have reduced growth rates and commonly die within 12 years of symptom expression. Growth reduction and death generally occur only in older stands where competition for root space (and, thus, for water and nutrients) has become significant. Once trees are affected, there is little likelihood of recovery, but it is possible to delay tree death for a few years by thinning and applying fertilizer.

While shortleaf pine is the most seriously damaged host, loblolly pine is damaged to a lesser extent. Littleleaf disease has also been reported on Virginia, pitch, slash, and longleaf pines. Historically this root rot complex was also responsible for significant losses of American chestnut trees.

Affected pine stands are found on the Piedmont Plateau from Virginia to Mississippi. Additional scattered pockets of disease occur in eastern Tennessee and southeastern Kentucky. The disease has its greatest impact in Alabama, Georgia, and South Carolina (fig. 17.10).

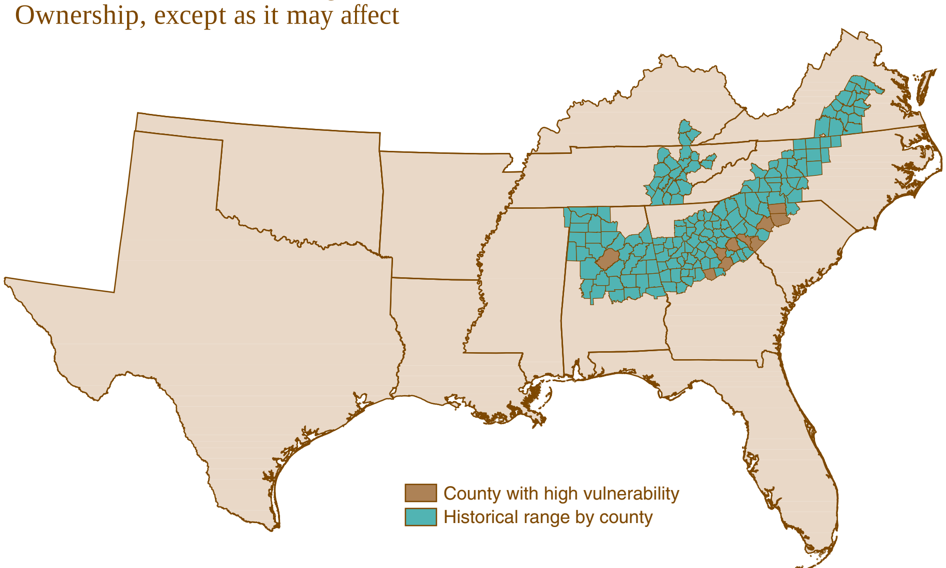

Figure 17.10—Historical range of littleleaf disease by county. Counties shown as highly vulnerable have soil and site characteristics that favor littleleaf disease.

Management strategies based on the work of Campbell, Copeland, and others have been extensively implemented throughout the range of the disease. Primary strategies are silvicultural (Anderson and Mistretta 1982; Mistretta 1984). Overall, the most used management strategies are to regenerate littleleaf sites with the more resistant loblolly pine, or to allow the site to revert to a predominantly hardwood cover with the expectation that the hardwoods will break the plow pan.

Generally, the level of management significantly affects the occurrence and severity of this disease. Intensively managed stands are regenerated before losses become serious. Less managed stands are likely to suffer serious loss and appear as generally unhealthy stands.

Ownership affects management of this disease. Industrial stands managed for short rotation products are essentially unaffected by this disease, while public land managed for older age timber or for old-growth aesthetics are vulnerable. Extensively managed, nonindustrial private land is susceptible to this disease, while intensively managed private land avoids the loss. Many managers of public land are implementing the strategy of converting to loblolly pine to avoid damage by this disease.

According to one estimate (Mistretta 1984), littleleaf disease was present in 35 percent of the commercial range of shortleaf pine and was severe enough to be a factor in timber management on about 4 million acres. Losses attributed to littleleaf disease exceed $15 million per year. However, because of appropriate management, there appears to have been a reduction in the amount and severity of littleleaf disease during the last several years.

As time passes, this disease will become less significant. However, it is difficult to project the ecological effects that will result from converting large acreages of shortleaf pine to loblolly pine.

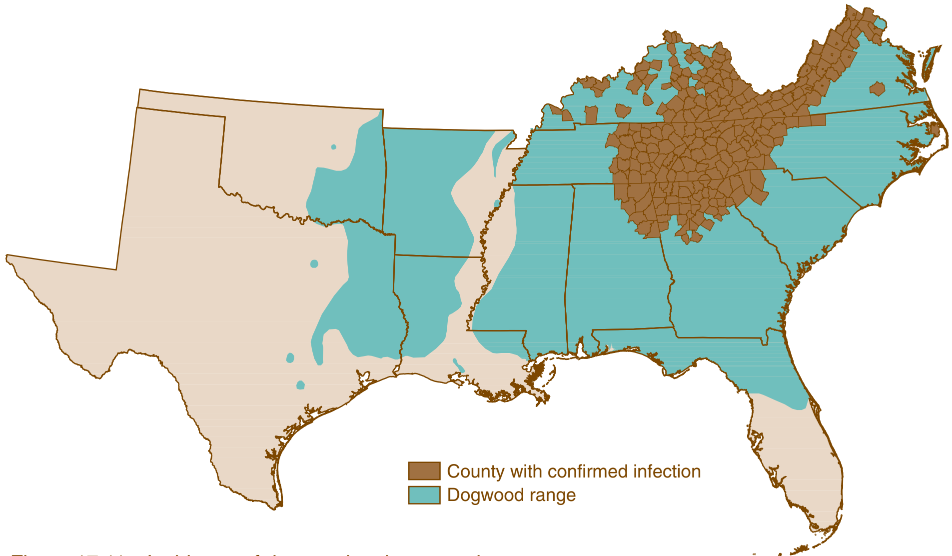

Figure 17.11—Incidence of dogwood anthracnose by county superimposed on the range of dogwood in the South (U.S. Department of Agriculture, Forest Service 1999).

Nonnative Diseases of Hardwoods

Dogwood anthracnose—The eastern flowering dogwood is a small tree that is valued as an ornamental and for its beauty in both forest and urban landscapes. It is also an important source of soft mast for over 100 different species of wildlife that feed on its berries (Kasper 2000). It is typically an understory tree found growing mixed with other hardwoods such as oak and hickory. The southern range of this disease is presented as figure 17.11.

Dogwood anthracnose is caused by an introduced fungus, *Discula destructiva*. It was first reported in the United States on flowering dogwood in 1978 and on western flowering dogwood in 1979.

For the past two decades, flowering dogwoods have been declining at an alarming rate. In some areas, they have been all but eliminated from the forest ecosystem above 3,000 feet in elevation.

Dogwood anthracnose affects all ages and sizes of dogwoods. The impact is most severe on fully shaded, understory trees, which are normally killed in 2 to 5 years. The most characteristic symptom of dogwood anthracnose is the yearly twig and branch death beginning in the lower part of the canopy (Britton and others 1993, Daughtrey and others 1988).

In the South, the most severe hazard for infection and mortality is at elevations above 3,000 feet and on shaded north-facing slopes. At lower elevations, the hazard is most severe in shaded, moist, and cool areas. Trees growing in full sunlight or on southern or western facing slopes at elevations below 3,000 feet sustain little damage from the disease.

Ornamentals are often disfigured without being killed, particularly if they are growing on open, sunny sites. In the last 10 years, the popularity of this tree as a landscape ornamental has declined because of the sudden destructive outbreak of dogwood anthracnose (Daughtrey and others 1996).

There is no known control of the disease for dogwoods growing in the forest, but vigorously growing trees tend to suffer less damage than weakened or stressed trees. Stress factors such as drought and winter injury appear to increase susceptibility (Anderson and others 1994). High-value trees can generally be protected by mulching, watering during droughts, and applying a fungicide.

While there is no practical control strategy for this disease in forest settings, hotter, drier climate in the southern and western portions of dogwood's range may limit its spread. Neither ownership nor intensity of management has had any significant effect on this disease.

A few disease-free trees have been found in the native population of dogwoods in areas of high dogwood mortality. An anthracnose-resistant flowering dogwood was introduced into the marketplace in the fall of 2000 (Windham and others 1998). Planting resistant trees in high-value areas is practical and wildlife may ultimately spread anthracnose-resistant seeds throughout the forest. However, the native population of dogwood is expected to continue to decline.

Beech bark disease—Beech bark disease is caused by a complex of two or more agents working in concert. The beech scale attacks the bark of American beech, creating infection courts subsequently colonized by the fungus *Nectria coccinea* var. *faginata*. This fungus causes cankers that coalesce and girdle host trees.

While the beech scale is now a common pest of the American beech, it is nonnative, having been introduced through Nova Scotia (Canada) in the late 1800s. There is speculation that the fungus was also introduced. Discussion on that point is somewhat pointless since a native fungus, *Nectria galligena* is also capable of inciting cankers and killing hosts after entering through scale-damaged bark. The scale must be considered the pivotal introduction that allowed the invasive spread of this disease complex (Houston and O'Brien 1983, Southern Appalachian Man and the Biosphere 1996). This disease complex was first identified in southern forests in the early 1990s.

The disease range continues to spread along a broad front. In the early phase of the disease cycle, more than 50 percent of the American beech trees 10 inches or larger in diameter at breast height are killed. Openings created by death or removal of the beech result in dense stands of root-sprouts, which

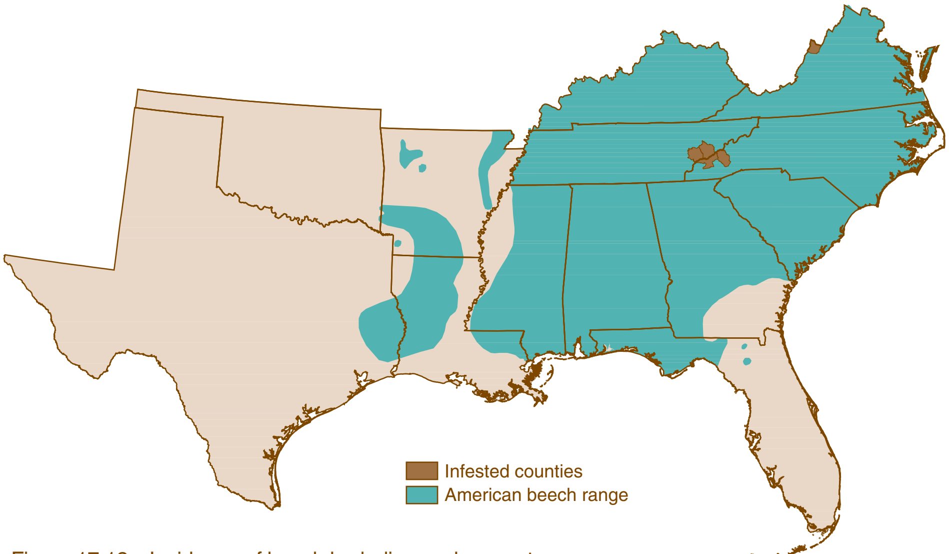

Figure 17.12—Incidence of beech bark disease by county superimposed on the range of American beech in the South (U.S. Department of Agriculture, Forest Service 1999).

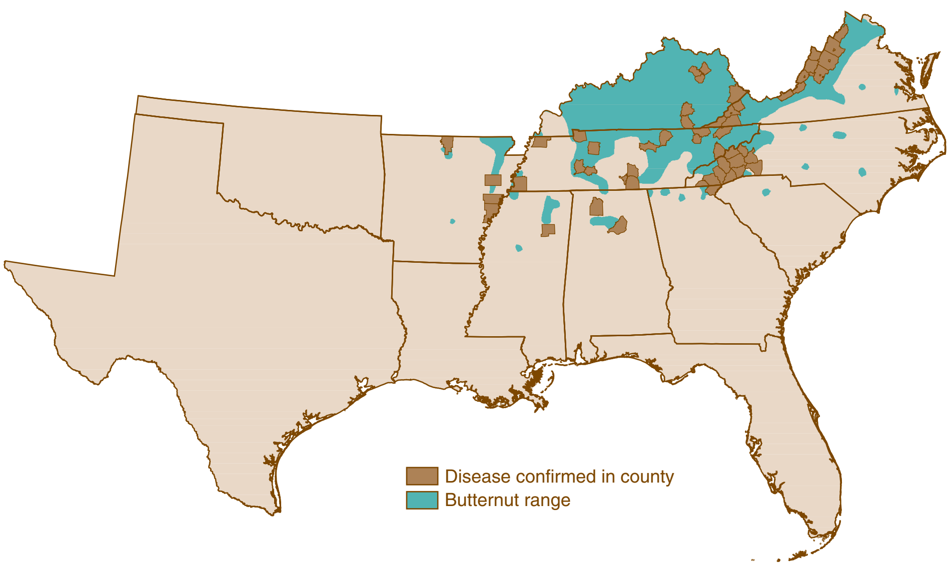

Figure 17.13—Incidence of butternut canker disease by county superimposed on the range of butternut in the South (U.S. Department of Agriculture, Forest Service 1999).

in turn yield stands abnormally rich in beech and deficient in its normal associates. In the second phase of the disease cycle, revegetated beech stands are attacked less severely, resulting in diseased survivors rather than in extensive mortality. Trees infected in this phase are rarely girdled, but they are generally severely deformed.

Since this disease complex affects only American beech, there is a direct relationship between the amount of beech in a stand and the intensity of the disease. Houston (1997) reports that "stand age and density, tree size, and species composition affect disease severity, especially in forests affected for the first time." The disease is expected to spread throughout the range of the host (fig. 17.12).

Silvicultural, chemical, and genetic strategies are available to manage this disease. Owners who depend on extensive (low intensity) management are expected to suffer significantly more quality (and value) loss than those who manage more intensively. Favoring genetic resistance is more effective in intensively managed forest stands.

Progeny from breeding programs designed to increase resistance have not been tested in field outplantings. They appear to hold promise, however, because some disease-free trees are known in most areas devastated by the disease. There is also some hope for biological control since a fungus and an insect are reported to attack the scale. High-value trees are sometimes protected with insecticides, but this method is impractical and uneconomical in the forest.

Damage to the South's beech resource has only just begun. Explosive buildups of scale population have not yet occurred in many places where the scales are known to be present. We anticipate significant additional mortality and deformation from this disease before prevention strategies are developed for use in forests.

Butternut canker—Butternut is a small to medium sized tree. Butternut typically is mixed with other hardwoods, such as black walnut, in the upland northern hardwood forest types (mapped as maple-beech-birch, oak-hickory, and oak-pine). Primarily found in riparian areas, this species was a significant producer of mast for wildlife. It hybridizes with other *Juglans* spp., such as heartnut, Japanese walnut, English walnut, little walnut, and Manchurian walnut. Although butternut is seldom found growing in great numbers, there is a strong desire to maintain a viable butternut population to preserve biodiversity (Clark 1965).

Butternut is being killed throughout its range in North America by a fungus, *Sirococcus clavigignenti-juglandacearam*. The fungus causes multiple cankers on the main stem and branches. Butternut canker has been found in 55 counties in the Southern United States (fig. 17.13). Butternut numbers have been dramatically reduced and it is now a candidate for listing under the Endangered Species Act.

Detailed examination of cankers indicates that butternut canker has been present in the United States since the early 1960s. Its origin is unknown but its rapid spread throughout the butternut range, its highly aggressive nature on infected trees, the scarcity of resistant trees, the lack of genetic diversity in the fungus, and the age of the oldest cankers (40 years) support the theory that it is a recent introduction.

Inventory data from FIA show a dramatic decrease in the number of live butternut trees in the United States. Surveys reveal that 77 percent of the butternut trees have been killed in North Carolina and Virginia.

Butternut canker kills trees of all ages. Trees in all settings and ownerships appear to be equally affected, except in urban settings that have been fertilized. (Fleguel 1996, Nicholls 1979).

Since butternut makes up less than 0.5 percent of the trees in the South, the overall impact of its loss to the forested ecosystem is considered by some to be minor. However, as butternut trees die, they are replaced by other species with a subsequent loss of biodiversity. The long-term outlook for butternut is not good; there is no known control for butternut canker. It appears the species will continue to decline and die, making up less and less of the forest population over time. At this time, the only hope for restoration is genetic selection and breeding.

The primary potential for control of the butternut canker is genetic. Disease-free trees are rare but have been found (Orchard and others 1981; Ostry and others 1994, 1996).

Chestnut blight—No event in the history of American forests is better known or sadder than the introduction of the chestnut blight fungus, *Cryphonectria parasitica*, from Asia, probably in the middle to late 1890s. The effects of this introduction will be felt for all time. The American chestnut tree was lost not only as a valuable timber species but also as the most important producer of hard mast for wildlife. The fungus continues to survive on infected sprouts from old chestnut rootstocks, various oaks, and some other hardwoods (Boyce 1961). Thus, there is virtually no hope the disease will be eradicated or that the American chestnut will naturally recover its preeminent position in eastern forest ecosystems.

Species associated with chestnut, including oaks, filled voids in forest stands left by the death of chestnut (Hepting 1974, Oak 1994). Unfortunately within about 60 years in the Southern Appalachians, the oaks that replaced the chestnut began to decline and die back (see Oak Decline) due in part to stressed growth on sites better adapted to chestnut.

No forest management practice of any intensity could overcome the ravages of chestnut blight nor did ownership affect disease progression. No control was found to stop the rapid devastation caused by this blight. Current attempts to cross American chestnuts with oriental varieties and then backcross to the American parent appear to offer a viable method of maintaining resistant chestnut in the forest (Schlarbaum 1988). Chromosome and gene manipulations now employed with other plants and animals may provide new avenues for resurrecting the American chestnut. Research into hypovirulence, the discovery of reduced pathogenicity because of a disease of *C. parasitica* itself, showed early promise as well (Anagnostakis 1978). Genetic engineering of the virus that causes a hypovirulent reaction has the potential to increase the efficiency of spread of hypovirulence in the fungal population and is currently being field-tested. Neither method has yet provided the needed answers but research is ongoing.

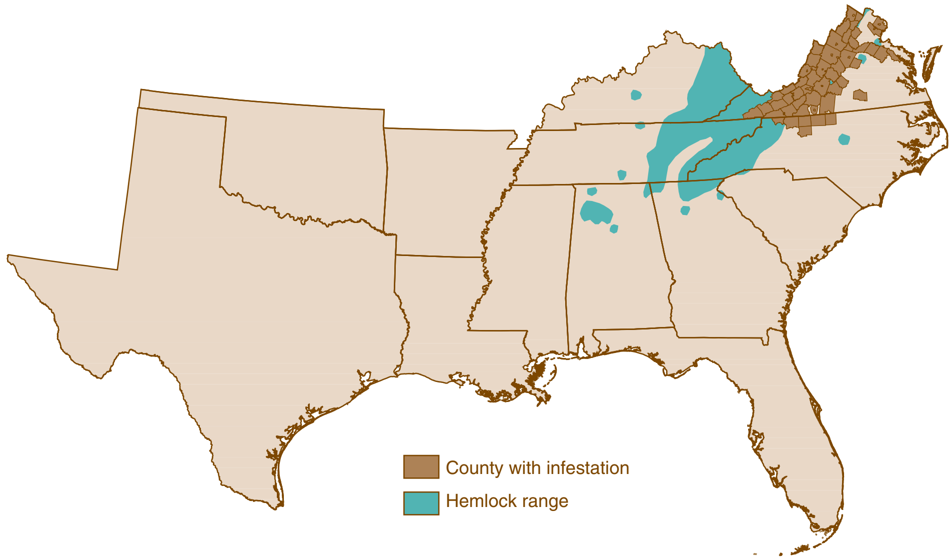

Figure 17.14—Incidence of hemlock woolly adelgid by county superimposed on the range of hemlock in the South (U.S. Department of Agriculture, Forest Service 1999).

Nonnative Insects

Hemlock woolly adelgid—The hemlock woolly adelgid (*Adelges tsugae*), an insect species native to Asia, was first identified in the Eastern United States in the early 1950s in Richmond, VA. It has recently expanded into the Southern Appalachians and threatens to spread throughout the ranges of eastern and Carolina hemlock. In the South, it is currently established in the mountains around the Shenandoah Valley, and it is spreading southward along the Blue Ridge (fig. 17.14).

Eastern hemlock is an important component of riparian ecosystems, providing cooling shade for streams, contributing nutrients for streams through litterfall, and providing winter shelter for wildlife. It may also be important as a feeding and nesting niche for neotropical migrant birds (Rhea and Watson 1994). The ecology of Carolina hemlock is less understood. It generally occupies more xeric sites on ridges and rock outcrops, but also probably provides cover and nesting sites for birds and small mammals.

Once infested by the adelgid, hemlocks are weakened, gradually defoliate, and become unable to refoliate or to produce cones. The adelgid causes mortality in all ages of both species. Mortality occurs after complete defoliation, generally within 5 years of initial infestation (McClure 1987).

Both eastern and Carolina hemlock are threatened. The adelgid could eliminate the limited population of Carolina hemlock within the next two decades.

There is suspected but unconfirmed genetic resistance to adelgids in both of the eastern hemlock species. Resistance is known to occur in hemlocks native to Asia and in the two species native to the Western United States. There are no known silvicultural strategies to prevent

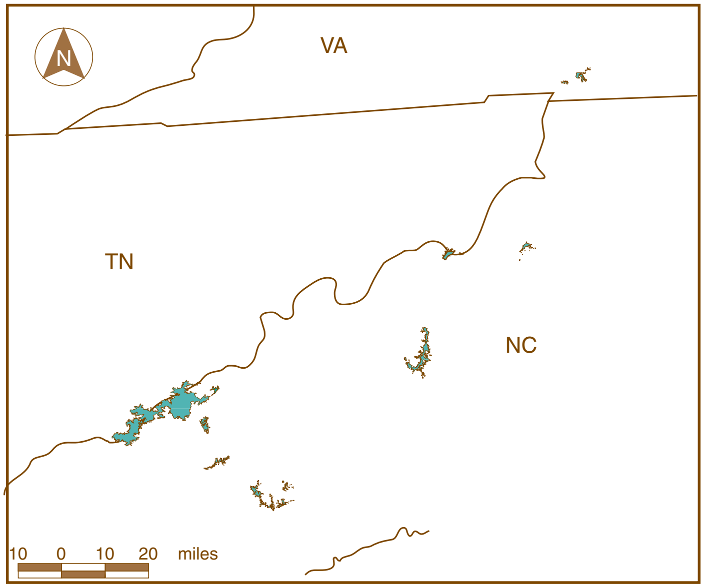

Figure 17.15—Location of spruce-fir type in western North Carolina, eastern Tennessee, and southern Virginia. Balsam woolly adelgid has colonized the entire host range (U.S. Department of Agriculture, Forest Service 1999).

adelgid-caused impact or mortality. Chemical spraying or soil treatment can protect individual hemlock trees, but such treatment is impractical for forest trees (Rhea 1996). Results of recent attempts at biocontrol of this pest are inconclusive. It appears that all untreated hemlocks, with the possible exception of small geographically isolated populations, could eventually be killed by the adelgid (Rhea 1996).

Balsam woolly adelgid in the Southern Appalachians—The impacts of balsam woolly adelgid (BWA) (*Adelges piceae*) were first documented in 1957 on Fraser fir in the Southern Appalachians. There are five major areas of spruce-fir forest in North Carolina, Tennessee, and Virginia (fig. 17.15). The majority of this forest type is on Federal land and is maintained for public use. These forests occur at high elevation and are highly valued scenic and recreation areas that attract several million visitors annually. The balsam woolly adelgid has infested Fraser fir in all five areas and impacts are evident.

Several laws have been enacted that direct the management of the Fraser fir and help resource managers make decisions dealing with the future of this tree. These laws help maintain the limited or threatened ecosystems and are key to the preservation of the spruce-fir forests. Fraser fir is under consideration for inclusion on the Federal endangered species list.

Several species of flora and fauna rely on mature spruce-fir habitat for survival. Many of these plants and animals are found only in this environment. Damage caused by the adelgid has put these species at greater risk.

The Fraser fir forests of the Southern Appalachians are declining (Dull and others 1988, Nicholas and Zedaker 1990). The BWA has eliminated 95 percent of the mature fir from the forest, fir mortality attributed to the BWA continues at a steady rate, and the residual fir population consists of trees generally less than 40 years old.

Ground-applied chemical controls have proven effective against BWA but none are economically or environmentally feasible in a forested situation. Aerial application of chemicals has proven ineffective.

Biological controls for the adelgid have been extensively studied, but so far no effective biocontrols have been found. In addition, natural enemies have had little effect on the thriving adelgid population.

Cultural control methods have also been attempted without success.

There is some speculation that BWA may ultimately eliminate Fraser fir by destroying its reproductive capacity. Reproduction of this species does occur but much less frequently than before BWA was present. Fraser fir survives to more than 40 years even when under pressure from the BWA, and at present it appears that the BWA will not eliminate spruce-fir forests at the high elevations of the Southern Appalachians. However, there remains the possibility that species dependent on mature fir canopies may be lost or that an additional stressor may cause the loss of the Fraser fir forest type.

Nonnative Insects of Hardwoods

Gypsy moth—The gypsy moth, *Lymantria dispar*, is native to Europe and Asia. In 1869, Leopold Trouvelot introduced the European strain of the gypsy moth into the United States. Since then, it has spread across the landscape of the Eastern United States, defoliating vast acreages of forest. The insect spread into northeastern Virginia in the early 1980s. By the middle 1990s, it had reached the eastern seaboard of North Carolina, and had infested much of Virginia. At the insect's current rate of spread, specialists predict that a significant portion of the Southeast will be infested in the next 30 years.

The gypsy moth causes its damage by feeding on and defoliating forest and shade trees during the caterpillar stage (Doane and McManus 1981, U.S. Department of Agriculture Forest Service and Animal and Plant Health Inpection Service 1995). Caterpillars feed on a wide range of trees and shrubs (Liebhold and others 1995, Zhu 1994) but prefer oaks.

Natural enemies, including small mammals and parasitic insects, often keep gypsy moth populations low (Elkinton and Liebhold 1990). Occasionally, however, populations increase above the capacity of these natural enemies to control. Then an outbreak occurs that can last for several years. Outbreaks culminate when populations collapse, either as the result of disease or starvation. The most important disease agents are the gypsy moth nucleopolyhedrosis virus and the gypsy moth fungus, *Entomophaga maimaiga* (Andreadis and Weseloh 1990, Hajek and others 1990).

Management of gypsy moth utilizes three strategies: eradication, suppression, and slowing the spread (Gottschalk 1993, U.S. Department of Agriculture Forest Service and Animal and Plant Health Inpection Service 1995). Eradication concentrates on the elimination of gypsy moth populations outside the quarantined area. Suppression concentrates on managing gypsy moth populations in the quarantine area to limit defoliation. Slowing the spread concentrates on limiting population spread along the leading edge of the quarantine area.

The gypsy moth is spreading into the South along a wide arc from the eastern shore of Virginia and North Carolina to the Appalachian Mountains in western Virginia. At this time, the impact of gypsy moth defoliation in the South is limited to Virginia and the northeastern shore of North Carolina (fig. 17.16).

The impact of repeated gypsy moth defoliation on the health of oak forests is significant (Campbell and Sloan 1977). Repeated severe defoliation of oaks weakens trees to such an extent that they may be attacked and killed by secondary pest organisms, such as the two-lined chestnut borer and Armillaria root rot (caused by *Armillaria mellea*). Extended drought intensifies the rate of death.

Species are attacked preferentially without respect to forest type. Highly favored species include northern red oak, basswood, and sweetgum. Species of limited suitability include maples, ash, beech, pine, and cherry. Species that are not favored or are avoided include yellow-poplar, blackgum, black locust, cypress, magnolia, and tupelo.

Increased intensity of management of forest stands may improve forest health, reduce susceptibility to defoliation by gypsy moth once stands are colonized, or remove individual trees and species that are vulnerable to damage. Overmature stands of red oaks, particularly scarlet and black oak, are highly vulnerable to loss after defoliation. Young, vigorously growing stands are thought to be less vulnerable to damage from gypsy moths. Alternatively, actively managed stands may be vulnerable to damage if they are defoliated soon after thinning. However, most silvicultural recommendations have not been experimentally verified at this time.

In a general sense, ownership does not influence impact. However, management objectives may limit treatment options for reducing outbreak populations of gypsy moth or they may limit opportunities to manage stand and species composition to favor nonpreferred species of trees.

Damaging populations of gypsy moths are managed by applying chemical or biological insecticides from the air and on the ground. Unfortunately, some treatments may adversely impact a nontarget species of crustaceans and insects, particularly rare species of moths and butterflies. Biological insecticides, including *Bacillus thuringiensis* var. *kurstaki*, a naturally occurring soil-borne bacterium, and Gypchek, a nucleo-polyhedrosis virus, are believed to have fewer negative environmental effects than other available treatments.

Very low-density populations of gypsy moths, particularly isolated populations, may be eliminated using a formulation of the sex pheromone of the female moth, or by mass trapping using the pheromone for bait. Insecticides are most often applied to residential areas where the caterpillar is considered to be a serious pest (U.S. Department of Agriculture Forest Service and Animal and Plant Health Inpection Service 1995). Treatment of uninhabited forests is generally only done to slow the spread of gypsy moths. Impact of this pest on the South's forests will increase as it continues to spread.

Outbreaks and their damage will be most conspicuous in the upland hardwood type, where oaks reach their greatest abundance. Bottomland hardwood and oak/pine forests will also sustain serious outbreaks.

How far south it will spread and how effective natural controls will prove to be are unknown.

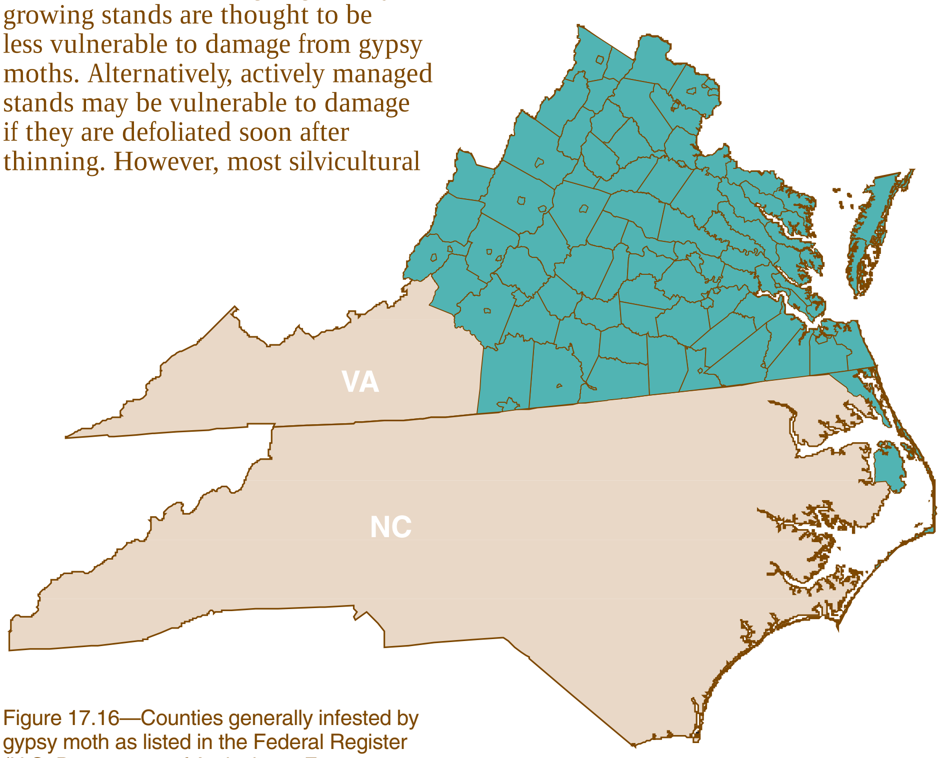

Figure 17.16—Counties generally infested by gypsy moth as listed in the Federal Register (U.S. Department of Agriculture, Forest Service 1999).

Discussion and Conclusions

Tables 17.1 and 17.2 summarize the current status of, current prevention and control strategies for, and likely changes in the amounts of damage that will be sustained from each of 21 forest pests in southern forests. We make no strong claims about the accuracy of these projections and provide them only as a useful summary.

Questions we have attempted to address concerning the health of the southern forests include:

- Are the effects of insect pests and diseases affected by forest type?
- What are the likely effects of large acreages of single-species plantations?
- What effect does intensive management have on insect and disease incidence?
- How will pest impacts differ among the major classes of land ownership?
- Will problems with nonnative insect and disease pests continue to increase?

Each of the pests discussed attacks a particular host or group of host species. Several of the pests discussed have the potential to eliminate their host species from the ecosystems in which they currently thrive.

Single-species planting, often called monoculture, is an economical way to produce wood or fiber of desired species rapidly. However, the concentration of single-species plantings over large areas offers great opportunities for forest pests that normally attack only the planted species or a small group of species that includes it. It

Table 17.1—Forest type listing with associated pest species

Forest type	Disease	Insect
White pine	Annosus root disease	Hemlock woolly adelgid
Hemlock	Annosus root disease	Balsam woolly adelgid
Spruce/fir	Annosus root disease	
Loblolly/shortleaf/ Virginia pine	Annosus root disease Fusiform rust Littleleaf disease	Bark beetles, not SPB Nantucket pine tip moth Pine reproduction weevils Southern pine beetle Texas leaf-cutting ant
Slash/longleaf pine	Annosus root disease Brown spot needle disease Fusiform rust	Bark beetles, not SPB Nantucket pine tip moth Pine reproduction weevils Southern pine beetle Texas leaf-cutting ant
Upland/northern hardwood	Beech bark disease Butternut canker Chestnut blight Dogwood anthracnose Oak decline Oak wilt	Forest tent caterpillar Gypsy moth Hardwood borers
Bottomland hardwood/cypress	Beech bark disease Dogwood anthracnose Oak wilt	Baldcypress leafroller Forest tent caterpillar Gypsy moth Hardwood borers
Oak/pine	Oak decline Oak wilt	Bark beetles, not SPB Forest tent caterpillar Gypsy moth Hardwood borers
Live oak	Oak Wilt	Hardwood borers

SPB = southern pine beetle.

seems obvious that populations of the pests that attack pine can expand and prosper in a pine monoculture. The fusiform rust fungus may be the outstanding example of a relatively minor pest becoming a major one because of plantation forestry.

Intensive forest management is a mixed blessing from the standpoint of pest management. While it is most commonly practiced in single-species plantations, and runs the risk of catastrophic losses to insects and diseases, it also offers great opportunities to minimize pest impacts. One of the primary objectives of intensive management is to keep individual trees vigorous, and such trees usually are less susceptible to pest damage than their slow-growing counterparts in unmanaged, less thrifty stands. In intensively managed stands it usually is practical to salvage trees that have been attacked by forest pests. In addition, healthy, intensively managed stands generally recover more quickly following a pest attack.

Risks of major losses to pests vary considerably by class of owner. Increasingly trees on public land are being grown in long rotations and in natural stands rather than plantations. Natural stands with mixed species composition have somewhat less risk of suffering catastrophic loss to forest pests. But susceptibility of individual trees increases as the trees age. Oak decline, for example, is taking a huge toll of aging oaks on public land.

When pest problems appear on industrial tracts, they are generally identified and dealt with promptly.

The same usually cannot be said for nonindustrial private land; the great diversity of owner objectives and management styles results in a variety of responses to pest problems. Most of the owners have little knowledge about pest problems and solutions, and many of their stands are not intensively managed. Commonly they are not even thinned before tree vigor starts to decline. In addition, desirable treatments often are not practical on the small tracts held by nonindustrial private landowners.

The greatest threat to the future health of southern forests is the introduction and spread of nonnative invasive pests. Once these pests are established, a lack of natural controls permits them to become extremely destructive and almost impossible to eliminate. Regulating the movement of plants and plant materials, and detecting and eradicating new pest introductions, are responsibilities of the USDA Animal and Plant Health Inspection Service (APHIS). The USDA Forest Service and State forestry organizations work closely with APHIS to prevent introductions and to eradicate them where they occur. Nevertheless, introductions continue to occur and eradication efforts often fail. The problem is not unique to the South or to the United States. It is an international problem of major proportions.

Among significant nonnative pests established in the South are the hemlock woolly adelgid, beech bark disease, dogwood anthracnose, the European gypsy moth, and the Formosan termite. Pests that are likely to be introduced include the Asian long-horned beetle, the pink hibiscus mealybug, and the Asian gypsy moth. Monitoring and suppression will continue to be important tools for preventing and managing these pests.

Risk assessment is one of the most important aspects of forest pest management. If the risk of a major loss is low, there is little point in spending a lot of money and disturbing environments to control a pest infestation. The USDA Forest Service has begun to evaluate areas at high risk from several pests. Areas are considered

Table 17.2—Summary of results of the individual forest pest analyses

Disease or pest	Native or nonnative pest	Type or species affected	Does impact vary with		Pest significance[a]		Are practical control strategies available?[b]	Research needs[c]
			Ownership?	Management intensity?	Past	Future		
Annosus root disease	Native	Pines in the pine types	Yes	Yes	5, 6	5, 6	PB, PC, PP, SC	
Baldcypress leaf roller	Native	Bald cypress in bottomland hardwood types	No	No	8	8	No	B, C
Balsam woolly adelgid	Nonnative	Fraser fir in the spruce-fir type	No	No	2	2	SC	B, C
Bark beetles (except southern pine beetle)	Native	Pines in the pine types	Yes	Yes	5, 6	5, 6, 7	SC	C
Beech bark disease	Nonnative	American beech in the northern hardwood types	No	No	NA	1	No	B, C
Brown spot needle disease	Native	Longleaf pine	Yes	Yes	5	5	PC, PP	
Butternut canker	Nonnative	Butternut in the northern hardwood types	No	No	1	1	No	C, G
Chestnut blight	Nonnative	Chestnut, oaks, and others in northern hardwood types	No	No	1	1	No	G
Dogwood anthracnose	Nonnative	Dogwoods in the northern hardwood types	No	No	1	1	No	G
Forest tent caterpillar	Native	Bottomland hardwood types	No	Yes	8	8	SB, SC	B
Fusiform rust	Native	Loblolly and slash pines in the pine types	Yes	Yes	5, 6	5, 6	PC, PG, PP, SC	G
Gypsy moth	Nonnative	Hardwoods—all types	No	Yes	1, 2, 4, 5, 6, 7	1, 2, 4, 5, 6, 7	PB, PC, PP, SP	B, G
Hemlock woolly adelgid	Nonnative	Hemlocks	No	No	NA	1	SP	B, G
Littleleaf disease	Nonnative	Shortleaf and loblolly pines	Yes	Yes	5, 6	5, 6	PC, SC	
Oak decline	Native	Oaks	Yes	Yes	1	1	PC	B, C
Oak wilt	Native	Oaks	Yes	Yes	2	1	SC, SP	C
Pine tip moth	Native	Hard pines	Yes	Yes	5, 6	5, 6	PC, SP	C
Pine reproduction weevils	Native	Pine	Yes	Yes	5, 6	5, 6	PC, SP	
Southern pine beetle	Native	Pines	Yes	Yes	3, 4, 5, 6, 7	3, 4, 5 6, 7	PC, SC, SP	C
Texas leaf-cutting ant	Native	Pine reproduction	No	No	5, 6	5, 6	SP	C, P
Woodborers	Native	Hardwoods pines	No	Yes	3	3	PC	C, P

[a] Pest significance: 1 = severe widespread ecological impacts, 2 = severe localized ecological impacts, 3 = significant tree mortality or decline, 4 = significant problem on reserved lands, 5 = significant problem on private and industrial forests, 6 = significant problem on unreserved public lands, 7 = significant problem in the urban/wildland interface, and 8 = moderate problem.

[b] Pest control strategies: prevention—PC = cultural practices, PG = genetic manipulation, PP = pesticidal tactics; suppression—SB = biological control, SC = cultural tactics, and SP = pesticidal control.

[c] Research needed: B = biocontrol, C = cultural tactics, G = genetic resistance enhancement, and P = prevention strategy.

to be at risk if tree mortality of 25 percent or more is expected during the next 15 years. Nationwide, some 59 million acres of forest are thought to be at risk from insects and disease-causing agents. Gypsy moths and southern pine beetles are the leading causes of risk in southern forests. Some 15 million southern acres are rated as high risk because of these insects (fig. 17.17).

The Forest Health Monitoring Program was established in 1990 to assess and report on the health of the Nation's forest ecosystems. It is a cooperative multi-agency effort. The Program provides for: (1) establishment of permanent plots throughout the Nation; (2) performance of aerial and ground surveys; (3) analysis of plot-based data from USDA Forest Service Forest Inventory and Analysis Units, national forest inventories, and forest health protection inventories; and (4) development of necessary methods to achieve assigned tasks.

Monitoring data support the conclusion that 85 to 90 percent of the trees in the South are healthy. These data also show that there are major concerns for the health of the forests in some areas (caused by oak decline, beech bark disease, and others), and also for some individual species of forest tree (eastern and Carolina hemlock, dogwood growing in specific conditions, and others).

Practical control methods for many pests are still lacking. Problems with treatment delivery, biology, public acceptance, economic practicality, adverse impact on nontarget species,

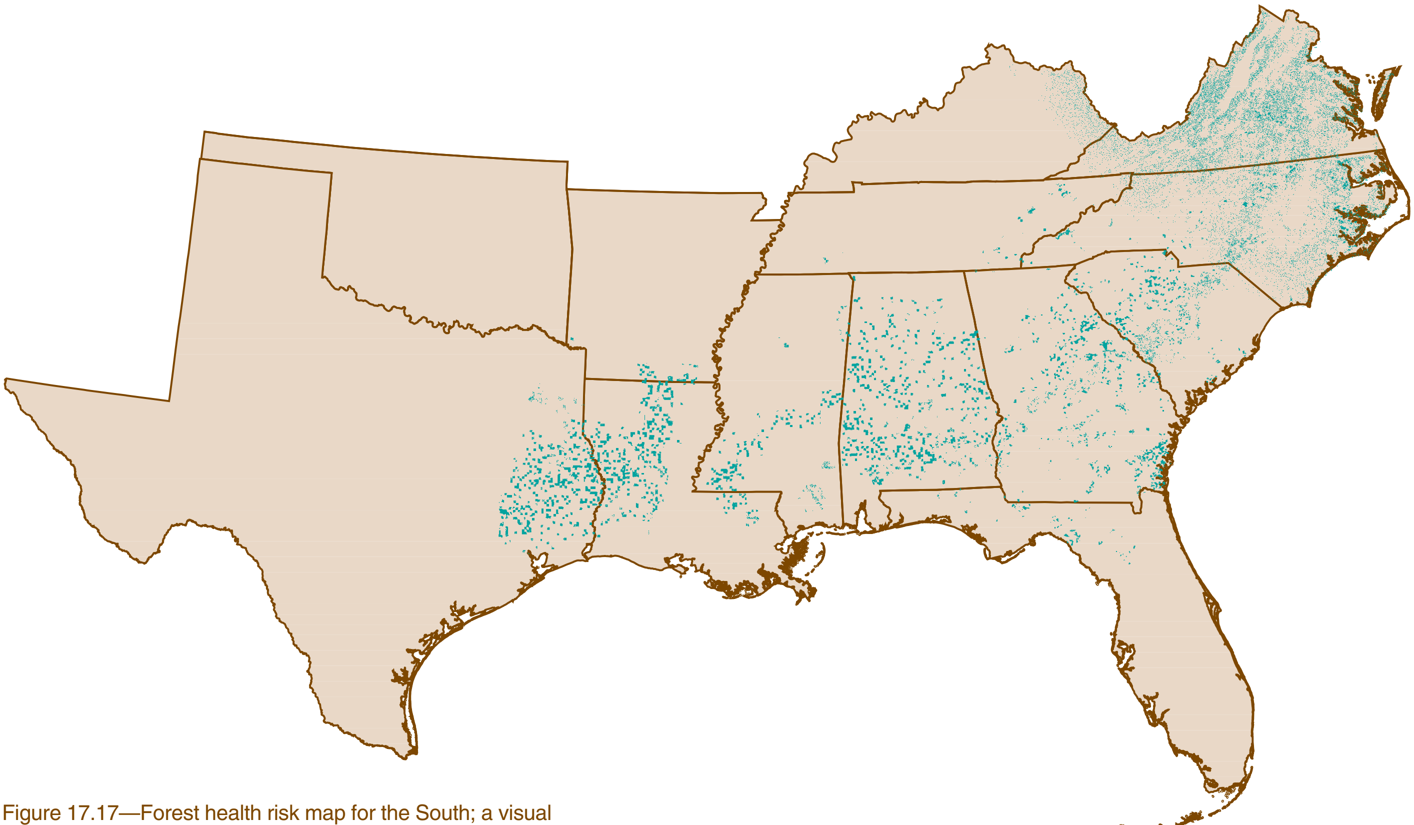

Figure 17.17—Forest health risk map for the South; a visual representation of risk of future tree mortality (Lewis 2000). The displayed results reflect intensity of risk and are not intended for site-specific analysis.

and many other obstacles affect development and deployment. The use of chemical pesticides in Federal forestry has declined due to the difficulty of procuring and maintaining EPA registration of products and also due to public pressure. Replacement silvicultural, genetic or biological strategies are often unavailable. Fragmentation of nonindustrial private ownerships makes it more difficult to implement control procedures there. Continued use of synthetic chemical pesticides will be necessary for the near future to keep pest problems manageable until alternative strategies become available.

IPM, the concurrent or consecutive use of a variety of tools or practices to control pests, is the overall process preferred by State and Federal agencies. Developing and implementing IPM for a particular pest is a complex process that requires considerable research. A systems model of IPM developed by Waters and Ewing (1974) (fig. 17.18) indicates the complexity of developing an IPM system for the southern pine beetle.

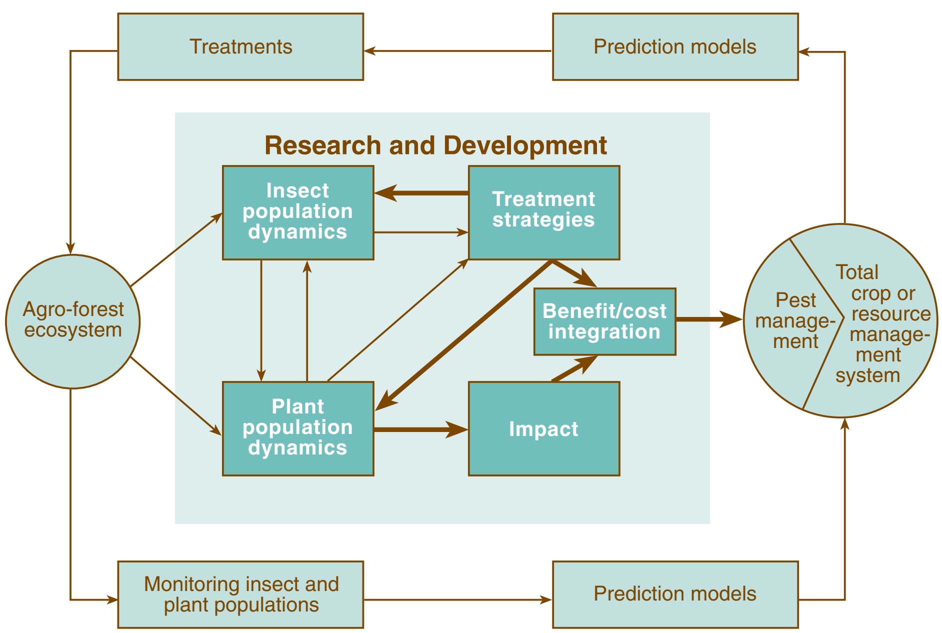

Figure 17.18—Waters and Ewing (1974) model of a potential IPM system for southern pine beetle control.

Research Needs

Significant data gaps were identified during preparation of this chapter. The most important pest management research needed includes:

- Continued investigation and development of tree resistance to butternut canker, chestnut blight, baldcypress leafroller, and several other pests.
- Continued development or enhancement of environmentally acceptable pest prevention and suppression treatments for all pests identified.
- Continued development of biopesticides and biological controls and prescription of their use in prevention and suppression programs for gypsy moth, SPB, ARD, and chestnut blight.
- Evaluation of the effectiveness of existing control measures, including "cut and leave" treatments for southern pine beetle control and silviculture for prevention of gypsy moth attack.
- Development of new hazard rating systems and validation of existing ones to identify areas that need treatment to prevent the occurrence of unacceptable losses to SPB, ARD, fusiform rust, and gypsy moth.
- Identification of potentially invasive species, along with the sites that are vulnerable to invasion.
- Development of methods for early detection of nonnative invasive species.

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Literature Cited

Anagnostakis, Sandra L. 1978. The American chestnut: new hope for a fallen giant. Bull. 777. New Haven, CT: Connecticut Agricultural Experiment Station. 9 p.

Anderson, R.L.; Knighten, J.L.; Windham, M. [and others]. 1994. Dogwood anthracnose and its spread in the South. Protect. Rep. R8–PR–26. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State & Private Forestry, Forest Pest Management. 10 p.

Anderson, R.L.; Powers, H.; Snow, G. 1980. How to identify fusiform rust and what to do about it. For. Bull. SA–FB/P24. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State & Private Forestry, Forest Insect and Disease Management. 12 p.

Anderson, Robert L.; Mistretta, Paul A. 1982. Management strategies for reducing losses caused by fusiform rust, annosus root rot, and littleleaf disease. Agric. Handb. 597. Washington, DC: U.S. Department of Agriculture, Forest Service. 30 p.

Andreadis, T.G.; Weseloh, R.M. 1990. Discovery of *Entomophaga maimaiga* in North American gypsy moth, *Lymantria dispar*. Proceedings of the National Academy of Science (U.S.). 87: 2461–2465.

Appel, David N.; Billings, Ronald F., eds. 1995. Oak wilt perspectives: Proceedings of the national oak wilt symposium. College Station, TX: Texas Forest Service, Texas Agricultural Experiment Station, Texas Agricultural Extension Service. 217 p.

Applegate, H.W. 1971. Annosus root rot mortality in once-thinned loblolly pine plantations in Tennessee. Plant Disease Reporter. 55: 625–627.

Balch, R.E. 1927. Dying oaks in the Southern Appalachians. Forest Worker. 3(7): 13.

Batzer, H.O.; Morris, R.C. 1978. Forest tent caterpillar. [Forest Insect and Disease Leafl. 9]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 8 p.

Beal, James A. 1926. Frost kills oak. Journal of Forestry. 24: 949–950.

Belanger, R.P.; Walkinshaw, C.H.; Anderson, R.L. 1991. How to select trees with fusiform rust for removal in thinning. Protect. Rep. R8 PR22. Atlanta: U.S. Department of Agriculture, Forest Service, Southeastern Area, Forest Pest Management. [Number of pages unknown].

Berisford, C.W. 1974. Comparisons of adult emergence periods and generations of the pine tip moths, *Rhyacionia frustrana* and *R. rigidana*. Annals of the Entomological Society of America. 67: 666–668.

Berisford, C.W. 1988. The Nantucket pine tip moth. In: Berryman, A.A., ed. Dynamics of forest insect populations: patterns, causes, and implications. New York: Plenum Publishing Corp.: 141–161.

Berisford, C.W.; Kulman, H.M. 1967. Infestation rate and damage by the Nantucket pine tip moth in six loblolly pine stand categories. Forest Science. 13: 428–438.

Boyce, J.S. 1961. Forest pathology. 3rd ed. New York: McGraw-Hill Book Co.: 285–292.

Britton, K.O.; Roncadori, R.W.; Hendrix, F.F. 1993. Isolation of *Discula destructiva* and other fungi from seeds of dogwood trees. Plant Disease. 77: 1026–1028.

Cameron, R. Scott; Billings, Ronald F. 1995. The Texas oak wilt suppression project: development, implementation, and progress to date. In: Appel, David N.; Billings, Ronald F., eds. Oak wilt perspectives: Proceedings of the national oak wilt symposium. College Station, TX: Texas Forest Service, Texas Agricultural Experiment Station, Texas Agricultural Extension Service: 139–145.

Campbell, R.W.; Sloan, R.J. 1977. Forest stand response to defoliation by gypsy moth. Forest Science Monogr. 19. 34 p.

Campbell, W.A.; Copeland, Otis L., Jr. 1954. Littleleaf disease of shortleaf and loblolly pines. Circ. 940. Washington, DC: U.S. Department of Agriculture. 41 p.

Cherret, J.M. 1986. History of the leaf-cutting ant problem. In: Lofgren, C.S.; Vander Meer, R.K., eds. Fire ants and leaf-cutting ants biology and management. Boulder, CO: Westview Press: 10–17.

Clark, F. 1965. *Juglans cinerea* L.: butternut. In: Fowells, H.A., ed. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture, Forest Service: 208–210.

Clarke, S.R. 1982. Dispersion of the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), in newly established loblolly pine plantation. Fayetteville, AR: University of Arkansas. 106 p. M.S. thesis.

Clarke, S.R.; Evans, R.E.; Billings, R.F. [In press]. Influence of pine bark beetles on the west Gulf Coastal Plain. Texas Journal of Science.

Conner, M.D.; Wilkinson, R.C. 1983. *Ips* bark beetles in the South. [Forest Insect and Disease Leafl. 129]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 8 p.

Cordell, Charles E.; Anderson, R.L.; Kais, A.G. 1989. How to identify and control brown-spot disease on longleaf pine. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 10 p.

Corneil, J.A.; Wilson, L.F. 1980. Pales weevil—rationale for its injury and control. Michigan Christmas Tree Journal. Fall: 16–17.

Coulson, R.; Witter, J. 1984. Forest entomology, ecology, and management. New York: John Wiley. 669 p.

Coulson, R.N.; Flamm, R.O.; Pulley, P.E. [and others]. 1986. Response of the southern pine bark beetle guild to host disturbance. Environmental Entomology. 15: 859–868.

Cram, M.M. 1994. Assessment of root disease and bark beetle association in thinned longleaf pine stands at the Savannah River Forest Station. Rep. 94–1–33. [Atlanta]: U.S. Department of Agriculture, Forest Service, Southern Region, Forest Health Protection. 12 p.

Czabator, F.J. 1971. Fusiform rust of southern pines—a critical review. Res. Pap. SO–65. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 39 p.

Daughtrey, M.L.; Hibben, C.R.; Britton, K.O. [and others]. 1996. Dogwood anthracnose: understanding a disease new to North America. Plant Disease. 80: 349–358.

Daughtrey, M.L.; Hibben, C.R.; Hudler, G.W. 1988. Cause and control of dogwood anthracnose in Northeastern United States. Journal of Arboriculture. 14(6): 159–164.

Dinus, R.J.; Schmidt, R.A. 1977. Management of fusiform rust in southern pines. In: Proceedings of a symposium. Gainesville, FL: University of Florida. 163 p.

Doane, C.C.; McManus, M.L., eds. 1981. The gypsy moth: research toward integrated pest management. Tech. Bull. 1584. Washington, DC: U.S. Department of Agriculture, Forest Service, Science and Education Agency, Animal and Plant Health Inspection Service. 757 p.

Doggett, C.A.; Grady, C.R.; Green, H.J. [and others]. 1977. Seedling debarking weevils in North Carolina. For. Note 31. Raleigh, NC: North Carolina Forest Service, Department of Natural and Economic Resources.15 p.

Dull, C.W.; Ward, J.D.; Brown, H.D. [and others]. 1988. Evaluation of spruce and fir mortality in the Southern Appalachian Mountains. Rep. R8–PR 13. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Pest Management. 92 p.

Dwyer, John P.; Cutter, Bruce E.; Wetteroff, James J. 1995. A dendrochronological study of black and scarlet oak decline in the Missouri Ozarks. Forest Ecology and Management. 75: 69–75.

Eikenbary, R.D.; Fox, R.C. 1965. The parasites of the Nantucket pine tip moth in South Carolina. Tech. Bull. 1017. Clemson, SC: South Carolina Agricultural Experiment Station. 9 p.

Eikenbary, R.D.; Fox, R.C. 1968. Arthropod predators of the Nantucket pine tip moth *Rhyacionia frustrana*. Annals of the Entomological Society of America. 61: 1218–1221.

Elkinton, J.S.; Liebhold, A.M. 1990. Population dynamics of gypsy moth in North America. Annual Review of Entomology. 35: 571–596.

Eyre, F.H. 1980. Southern forest region. In: Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters: 51–77.

Fettig, C.J.; Berisford, C.W. 1999. Nantucket pine tip moth phenology in eastern North Carolina and Virginia: implications for effective timing of insecticide application. Southern Journal of Applied Forestry. 23: 30–38.

Fitzgerald, T.D. 1995. The tent caterpillars (Cornell series in arthropod biology). Ithaca, NY: Cornell University Press. 303 p.

Fleguel, V. Rosemary. 1996. A literature review of butternut and the butternut canker. Inform. Rep. 20. Ontario, Canada: Ministry of Natural Resources, Eastern Ontario Model Forest. 32 p.

Froelich, R.C.; Cowling, E.B.; Collicott, L.C.; Dell, T.R. 1977. *Fomes annosus* reduces height and diameter growth of planted slash pine. Forest Science. 23: 299–306.

Gottschalk, K.W. 1993. Silvicultural guidelines for forest stands threatened by gypsy moth. Gen. Tech. Rep. NE–171. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 49 p.

Graham, S.A. 1959. Control of insects through silvicultural practices. Journal of Forestry. 57: 281–283.

Grosman, D.M.; Billings, R.F.; McCook, F.A.; Upton, W.W. 1999. Influence of harvest date and silvicultural practices on the abundance and impact of pine reproduction weevils in western gulf pine plantations. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 565–568.

Gysel, L.W. 1957. Acorn production on good, medium, and poor sites in southern Michigan. Journal of Forestry. 55: 570–574.

Hajek, A.E.; Humber, R.A.; Elkinton, J.S. [and others]. 1990. Allozyme and RFLP analyses confirm *Entomophaga maimaiga* responsible for 1989 epizootics in North American gypsy moth populations. Proceedings of the National Academy of Science (U.S.A.). 87: 6979–6982.

Harper, J.D.; Abrahamson, L.P. 1979. Forest tent caterpillar control with aerially applied formulations of *Bacillus thuringiensis* and dimilin. Journal of Economic Entomology. 72: 74–77.

Haugen, D.A.; Stephen, F.M. 1983. Developmental rates of Nantucket pine tip moth [*Rhyacionia frustrana* (Comstock)] (Lepidoptera: Tortricidae) life stages in relation to temperature. Environmental Entomology. 13: 56–60.

Hepting, G.H. 1974. Death of the American chestnut. Journal of Forest History. 18: 60–67.

Hoffard, W.H.; Marx, D.H.; Brown, H.D. 1995. The health of southern forests. Protect. Rep. R–8 PR27. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 36 p.

Houston, David R. 1997. Beech bark disease. In: Britton, Kerry O., ed. Exotic pests of eastern forests: Proceedings of a conference. Nashville, TN: Tennessee Exotic Plant Pest Council: 29–41. In cooperation with: U.S. Department of Agriculture, Forest Service.

Houston, David R.; O'Brien, James T. 1983. Beech bark disease. [Forest Insect and Disease Leafl. 75]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 8 p.

Kais, Albert G. 1989. Brown spot needle blight. In: Cordell, Charles E.; Anderson, Robert L.; Hoffard, William H. [and others], tech. coords. Forest nursery pests. Agric. Handb. 680. Washington, DC: U.S. Department of Agriculture, Forest Service: 26–28.

Kasper, C.A. 2000. Flowering dogwood (*Cornus florida*). Windstar Wildlife Institute. http://www.windstar.org/features/clearinghouse/a_flowerin.htm. [Date accessed: August 5, 2002].

Kruse, J.J. 2000. *Archips goyerana* n. sp. (Lepidoptera: Tortricidae), an important pest of baldcypress (Taxodiaceae) in Louisiana and Mississippi. Proceedings of the Entomological Society of Washington. 102: 741–746.

Lewis, Joseph; Weiss, Melvyn. 2000. Forest health risk mapping. [Washington, DC]: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Forest Health Protection. 1 p.

Liebhold, A.M.; Gottschalk, K.W.; Muzika, Rose-Marie [and others]. 1995. Suitability of North American tree species to gypsy moth: a summary of field and laboratory tests. Gen. Tech. Rep. NE–211. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 34 p.

MacDonald, William L. 1995. Oak wilt: an historical perspective. In: Appel, David N.; Billings, Ronald F., eds. Oak wilt perspectives: Proceedings of the national oak wilt symposium. College Station, TX: Texas Forest Service, Texas Agricultural Experiment Station, Texas Agricultural Extension Service: 7–13.

Matthews, F.R.; Anderson, R.L. 1979. How to save your fusiform rust infected pines by removing cankers. Bull. SA–FB/P7. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Insect and Disease Management. 6 p.

McClure, M.S. 1987. Biology and control of hemlock woolly adelgid. Bull. 851. New Haven, CT: Connecticut Agricultural Experiment Station. 9 p.

Millers, I.; Shriner, D.S.; Risso, D. 1990. History of hardwood decline in the Eastern United States. Gen. Tech. Rep. NE–126. Durham, NH: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry, Forest Health Protection. 75 p.

Mistretta, Paul A. 1984. Littleleaf disease. [Forest Insect and Disease Leafl. 20]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 6 p.

Morris, C.L. 1970. Volume losses from *Fomes annosus* in loblolly pine in Virginia. Journal of Forestry. 68: 283–294.

Moser, J.C. 1984. Town ant. In: Proceedings of the 10th anniversary of the east Texas forest entomology seminar. Misc. Publ. MP–1553. College Station, TX: Texas Agricultural Experiment Station: 47–52.

Nicholas, N.S.; Zedaker, S.M. 1990. Forest decline and regeneration success of the Great Smoky Mountains spruce-fir [Abstract]. In: Smith, E.R., ed. Proceedings: the first annual southern man and the biosphere conference. TVA/LR/NRM–90/8. [Norris, TN]: Tennessee Valley Authority: [Number of pages unknown].

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Nicholls, T.H. 1979. Butternut canker. In: Proceedings of the symposium on walnut insects and diseases. Gen. Tech. Rep. NC–52. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 73–82.

Nord, J.C.; Ragenovich, I.; Doggett, C.A. 1984. Pales weevil. [Forest Insect and Disease Leafl. 104]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 8 p.

Nowak, J.T.; Berisford, C.W. 2000. Effects of intensive management practices on insect infestation levels and loblolly pine growth. Journal of Economic Entomology. 93: 336–341.

Oak, S.; Tainter, F.; Williams, J.; Starkey, D. 1996. Oak decline risk rating for the Southeastern United States. Annals des Sciences Forestiere. 53: 721–730.

Oak, S.W. 1994. Oak decline. In: Ferguson, Carol; Bowman, Pamela, eds. Threats to forest health in the Southern Appalachians. Gatlinburg, TN: Southern Appalachian Man and the Biosphere Cooperative: 9–13.

Oak, Steven W.; Courter, Anthony. 2000. Modeling oak decline effects on forest composition and structure change using the forest vegetation simulator [Abstract]. In: Anon. Proceedings of the first joint meeting of the northeast and southwide forest disease workshops. Morgantown, WV: West Virginia University. [Not paged].

Oak, Steven W.; Croll, Philip M. 1995. Evaluation of oak decline risk rating using the CISC database on the Cherokee National Forest, TN. Rep. 95–1–22. [Atlanta]: U.S. Department of Agriculture, Forest Service, Southern Region, Forest Health Protection. 11 p.

Oak, Steven W.; Huber, Cindy M.; Sheffield, Raymond M. 1991. Incidence and impact of oak decline in western Virginia 1986. Resour. Bull. SE–123. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 16 p.

Oak, Steven W.; Starkey, Dale A.; Dabney, Joseph M. 1988. Oak decline alters habitat in southern upland forests. Proceedings of the annual conference of the Southeastern Association of Fish and Wildlife Management Agencies. 42: 491–501.

Orchard, L.P.; Guries, R.P.; Kuntz, J.E. 1981. Butternut canker: screening seedlings for disease resistance [Abstract]. Phytopathology. 71: 247.

Ostry, M.; Mielke, M.; Skilling, D. 1994. Butternut—strategies for managing a threatened tree. Gen. Tech. Rep. NC–165. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Ostry, M.E.; Mielke, M.E.; Anderson, R.L. 1996. How to identify butternut canker and preserve butternut. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. [Number of pages unknown].

Paine, T.D.; Birch, M.C.; Svihra, P. 1981. Niche breadth and resource partitioning by four sympatric species of bark beetles (Coleoptera: Scolytidae). Oecologia. 48: 1–6.

Price, Terry S.; Doggett, Coleman; Pye, John M.; Smith, Bryan. 1998. A history of southern pine beetle outbreaks in the Southeastern United States by the southeastern forest insect working group. Macon, GA: Georgia Forestry Commission. 72 p.

Rexrode, Charles O.; Brown, H. Daniel. 1983. Oak wilt. [Forest Insect and Disease Leafl. 29]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 6 p.

Rhea, J.R. 1996. Forest health evaluation of hemlock woolly adelgid, *Adelges tsugae*, infestations within the George Washington, Jefferson National Forests, VA. Rep. 96–1–17. [Atlanta]: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Health Protection. 7 p.

Rhea, J.R.; Watson, J.K. 1994. Evaluation of hemlock woolly adelgid on the Shenandoah National Park, 1993. Rep. 94–1–22. [Atlanta]: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Health Protection. 8 p.

Robbins, K. 1984. Annosus root rot in eastern conifers. [Forest Insect and Disease Leafl. 76]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 9 p.

Schlarbaum, S.E. 1988. Returning the American chestnut to the forests of North America. Katuah Journal. 21, fall: 6, 7, 23.

Schmidt, R.A. 1998. Fusiform rust disease of southern pines: biology, ecology, and management. Tech. Bull. 903. Gainesville, FL: University of Florida. 14 p.

Smith, R.H.; Lee, R.E., III. 1972. Black turpentine beetle. [Forest Pest Leafl. 12]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 8 p.

Solomon, J.D. 1995. Guide to insect borers of North American broadleaf trees and shrubs. Agric. Handb. 706. Washington, DC: U.S. Department of Agriculture, Forest Service. 706 p.

Southern Appalachian Man and the Biosphere (SAMAB). 1996. Beech bark disease. In: the southern appalachian assessment terrestrial technical report. Rep. 5 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region: 111.

Speers, C.F. 1974. Pales and pitch-eating weevils: development in relation to time pines are cut in the Southeast. Res. Note SE–207. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Stairs, G.R. 1971. Use of viruses for microbial control of insects. In: Burges, H.D.; Hussey, N.W., eds. Microbial control of insects and mites. New York: Academic Press: 97–123.

Staley, John M. 1965. Decline and mortality of red and scarlet oaks. Forest Science. 11: 2–17.

Stambaugh, W.J. 1989. Annosus root disease in Europe and the Southeastern United States: occurrence, research, and historical perspective. In: Otrosina, William J.; Scharpf, Robert F., tech. coords. Proceedings of the symposium on research and management of annosus root disease (*Heterobasidion annosum*) in Western North America. Gen. Tech. Rep. PSW–116. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 3–9.

Starkey, Dale A.; Anderson, Robert L.; Young, Carol H. [and others]. 1997. Monitoring incidence of fusiform rust in the South and change over time. Protect. Rep. R8–PR30. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Health Protection. 29 p.

Starkey, Dale A.; Mangini, Alex; Oliveria, Forrest [and others]. 2000. Forest health evaluation of oak mortality and decline on the Ozark National Forest, 1999. Rep. 2000–02–02. [Atlanta]: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Health Protection. 31 p.

Starkey, Dale A.; Oak, Steven W.; Ryan, George [and others]. 1989. Evaluation of oak decline areas in the South. Protect. Rep. R8 PR–17. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region, State and Private Forestry, Forest Pest Management. 43 p.

Swain, K.M.; Remion, M.C. 1981. Direct control of the southern pine beetle. Agric. Handb. 575. Washington, DC: U.S. Department of Agriculture. 15 p.

Tainter, F.H.; Baker, F.A. 1996. Principles of forest pathology. New York: John Wiley. 805 p.

Tainter, F.H.; Retzlaff, W.A.; Starkey, D.A.; Oak, S.W. 1990. Decline of radial growth in red oaks is associated with short-term changes in climate. European Journal of Forest Pathology. 20: 95–105.

Texas Forest Service. 1982. Texas forest pest report 1980–1981. Publ. 127. College Station, TX: Texas Forest Service. 39 p.

Thatcher, R.C. 1960a. Bark beetles affecting southern pines: a review of current knowledge. Occas. Pap. 180. Washington, DC: U.S. Department of Agriculture, Forest Service. 25 p.

Thatcher, R.C. 1960b. Influence of the pitch-eating weevil on pine regeneration in east Texas. Forest Science. 6: 354–361.

Thatcher, R.C.; Barry, P.J. 1982. Southern pine beetle. [Forest Insect and Disease Leafl. 49]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 6 p.

Thatcher, R.C.; Conner, M.D. 1985. Identification and biology of southern pine bark beetles. Agric. Handb. 634. Washington, DC: U.S. Department of Agriculture, Forest Service, and Cooperative State Research Service. 14 p.

Thatcher, R.C.; Mason, G.N.; Hertel, G.D. 1986. Integrated pest management in southern pine forests. Agric. Handb. 650. Washington, DC: U.S. Department of Agriculture, Forest Service. 38 p.

Thatcher, R.C.; Searcy, J.L.; Coster, J.E.; Hertel, G.D., eds. 1980. The southern pine beetle. Tech. Bull. 1631. Washington, DC: U.S. Department of Agriculture, Forest Service, Science and Education Administration. [Number of pages unknown].

U.S. Department of Agriculture, Forest Service. 1971. Thinning pine plantations in 1971 and after. [Unnumbered For. Manag. Bull.]. Atlanta: U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry, Forest Insect and Disease Management. 6 p.

U.S. Department of Agriculture, Forest Service. 1985a. Black turpentine beetle and *Ips* beetles. In: Insects of eastern forests. Misc. Publ. 1426. Washington, DC: U.S. Department of Agriculture, Forest Service: 346–347, 358–361.

U.S. Department of Agriculture, Forest Service. 1985b. Forest tent caterpillar. In: Insects of eastern forests. Misc. Publ. 1426. Washington, DC: U.S. Department of Agriculture, Forest Service: 204–205.

U.S. Department of Agriculture, Forest Service. 1992. Pest and pesticide management in southern forests. Manag. Bull. R8–MB 60. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 46 p.

U.S. Department of Agriculture, Forest Service; Animal and Plant Health Inspection Service. 1995. Gypsy moth management in the United States: a cooperative approach. [Unnumbered Rep.]. Washington, DC: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Vilela, E.F. 1986. Status of leaf-cutting ant control in forest plantations in Brazil. In: Lofgren, C.S.; Vander Meer, R.K., eds. Fire ants and leaf-cutting ants biology and management. Boulder, CO: Westview Press: 399–408.

Waller, D.A. 1986. The foraging ecology of *Atta texana* in Texas. In: Lofgren, C.S.; Vander Meer, R.K., eds. Fire ants and leaf-cutting ants biology and management. Boulder, CO: Westview Press: 146–158.

Wargo, Philip M. 1977. *Armillaria mellea* and *Agrilus bilineatus* and mortality of defoliated oak trees. Forest Science. 23: 485–492.

Wargo, Philip M.; Houston, David R.; LaMadeleine, Leon A. 1983. Oak decline. [Forest Insect and Disease Leafl. 165]. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 8 p.

Warren, L.O. 1985. Primary hymenopterans parasites of Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock). Journal of Entomological Science. 20: 383–389.

Waters, W.E.; Ewing, B. 1974. Development and role of predictive modeling in pest management systems-insects. In: Tummalla, R.L.; Haynes, D.L.; Croft, B.A. Modeling for pest management concepts, techniques, and applications. East Lansing, MI: Michigan State University: 19–27.

Webb, J.W.; Berisford, C.W. 1978. Temperature modification of flight and response to pheromones in *Rhyacionia frustrana*. Environmental Entomology. 7: 278–280.

Windham, M.T.; Graham, E.T.; Witte, W.T. [and others]. 1998. *Cornus florida* “Appalachian Spring”: a white flowering dogwood resistant to dogwood anthracnose. Horticultural Science. 33: 1265–1267.

Zhu, Z. 1994. Forest density mapping in the lower 48 States: a regression procedure. Res. Pap. SO–280. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 11 p.

How have abiotic factors, including environmental stressors such as air pollution, influenced the overall health of the South's forests, and what are future effects likely to be?

Chapter 18:
Abiotic Factors

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Key Findings

- Sulfur deposition will continue to decrease and subsequently have less of a negative impact on forest ecosystem nutrient cycling, whereas future nitrogen deposition will be beneficial to most southern forests, which are nitrogen limited.
- High-elevation spruce-fir forests in the Southern Appalachian Mountains are the only forests in which significant damage is linked to acid deposition.
- The overall health of hardwoods, oak-pine, and southern pine forests has not been shown to be adversely affected by acid deposition.
- Regionally, there is no evidence that acid precipitation is causing significant damage to stream chemistry in the Southern United States. Water quality in some streams in the Southern Appalachian Mountains is decreasing.
- Ozone-related annual growth reductions for pine seedlings across the South are probably between 2 and 5 percent. Tree-water stress or forest drought is thought to protect seedlings from the negative effects of ozone. Any protective benefits provided by drought stress for seedlings are likely offset by growth and productivity reductions.
- Southern pines typically do not show visible symptoms of ozone (O_3) injury under ambient O_3 conditions, but growth of mature southern yellow pines is being reduced by current ambient ozone levels at annual rates that vary from 0 to 10 percent per year.
- Continued increases in ozone concentrations will likely have significant negative impacts on pine forests in the South.
- Forest area and growth rates could increase across the South with moderate increases in air temperatures and carbon dioxide concentrations during the 21st century. Severe temperature increases could negatively affect forest productivity and area, especially if precipitation rates do not increase to compensate for increased water demands.
- Carbon storage in southern forest ecosystems, including public, private, and industrial forests, could make a significant contribution to carbon sequestration. Future policies, incentive programs, and forest management intensity will affect carbon sequestration rates.
- Land use change, not climate change or atmospheric chemistry, has been and probably will continue to be the most important determinant of carbon storage, uptake, and release in terrestrial ecosystems.
- Existing climate change models do not provide adequate information to forecast changes in location, extent, frequency, or intensity of extreme weather events and their impacts on forest ecosystems. Potential increases in air temperature and changes in precipitation patterns may contribute to increased frequency or intensity of some events.
- Detailed spatial and temporal predictions of abiotic stressor effects on forest sustainability are not possible without long-term improvements in regional monitoring and studies designed to understand specific and integrated broad-scale stress responses at forest ecosystem, community, and species levels.

Introduction

The sustainability of southern forests could be threatened by the interactions of biotic and abiotic stressors (McLaughlin and Percy 1999). Environmental factors such as temperature, precipitation, atmospheric carbon dioxide (CO_2) and O_3 concentrations, and acid deposition affect forest processes such as carbon, water, and nutrient fluxes. These processes are the foundation of forest ecosystems, and abnormally large variability in their size, timing, or location may influence forest sustainability. Therefore, from an ecosystem perspective, changes in forest processes may be indicators of long-term forest function and health.

Sulfur and nitrogen deposition have been indicted as contributors to forest degradation, especially in the high-elevation red spruce and Fraser fir forests that occupy the ridges of the Appalachian Mountains (McLaughlin and Kohut 1992). In an effort to manage and sustain spruce-fir and hardwood forests in a way that does not compromise the ability of future generations to meet their needs, the current and future impacts of sulfur and nitrogen deposition on overall forest health in the Southern United States must be addressed.

Ground level (tropospheric) O_3 is an air pollutant that affects U.S. forests (U.S. Environmental Protection Agency 1996). At current ambient levels, O_3 can decrease tree growth, increase the probability of mortality, cause visible foliar damage, and alter forest successional patterns (Flagler and Chappelka 1996, McLaughlin and Downing 1995, Teskey 1996). For these reasons, current and projected O_3 impacts on southern forests are addressed in this Assessment.

Climate influences the establishment and growth of forest trees, affecting the extent and quality of forest ecosystems. The spatial and temporal distribution of air temperature and precipitation is the primary climatic factor shaping forests. Human activities contribute significantly to current global climate change (Dale and others 2000), predominantly due to the increasing concentration of greenhouse gases such as CO_2. Since the beginning of the industrial revolution, CO_2 levels have been steadily increased by fossil fuel burning and land use changes (Sarmiento and Wofsy 1999; U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). Even if changes in CO_2 concentration did not effect climate changes, they would affect plant growth.

Independently developed climate change scenarios are generated with transient general circulation models (GCMs) that simulate atmospheric dynamics under a gradual doubling in greenhouse gas concentrations from about 1895 to 2100. Emissions of CO_2 to the atmosphere are predicted to increase from 7.4 gigatons per year in 1997 to 26 gigatons per year by 2100 (U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). For this Assessment, these scenarios are used with ecological process models to investigate the potential effects of climate change on forest ecosystems.

Forest carbon sequestration, the ability of forests to store and release carbon, is currently an important issue debated in the policy arena. Carbon stored in forests affects the amount of carbon contributing to the increasing atmospheric CO_2 concentration. Reductions in carbon emissions have been proposed as a mitigation strategy for rising atmospheric CO_2, which may be causing global warming. Rising atmospheric CO_2 levels could also be mitigated by increasing carbon sequestration through forestry and other land management activities. Terrestrial ecosystems have enormous potential to capture CO_2 and store carbon.

Climate change also could generate forest stress, and extreme weather events can cause disturbances that shape forest systems by influencing their composition, structure, and functional processes. We discuss the effects of these disturbances and their relationship to changing temperature and precipitation patterns.

Biotic stressors such as insects and pathogens have major negative impacts on forest ecosystems; in the United States, they cause severe damage on an average of more than 50 million acres per year, costing $2 billion a year (Dale and others 2000). Biotic stressors are the focus of chapter 17.

Each of the abiotic stressors—methods, data sources, results, discussion, and conclusions—are discussed separately. Current abiotic stressors have been described for different coarse-scale studies. Attempts at regional-scale characterizations and future predictions are underway and are highlighted when feasible.

It is important to recognize the integrated nature of these abiotic stressors and their cumulative effects on forest ecosystems. This integration is referenced throughout the chapter. It is imperative that readers consider cumulative integrated effects when interpreting the results and conclusions from this chapter.

Acid Deposition

Acid Deposition Methodology: Current Conditions

Acid deposition occurs when emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) react with atmospheric water, oxygen, and oxidants to form acidic compounds. Mild solutions of nitric and sulfuric acids are formed and fall as acid precipitation. Sulfur and nitrogen deposition was first described as a problem in Europe in the early 19th century and has been studied extensively in North America since the 1970s (Blancher 1991). Sulfur and nitrogen deposition can impair tree growth in several ways. They can leach calcium and magnesium from soils where base cation stores are very low, and the ability of the ecosystems to retain sulfur or nitrogen is minimal (McLaughlin and others 1998). Acid deposition may also involve the release of toxic elements such as aluminum from the soil, adversely affecting biological processes and living organisms (Malmer 1976). Nutrient loss and soil degradation have been observed in some hardwood forests (Swank and Vose 1997). However, pine, hardwood, and mixed (oak-pine) forests experience slower losses of base cation

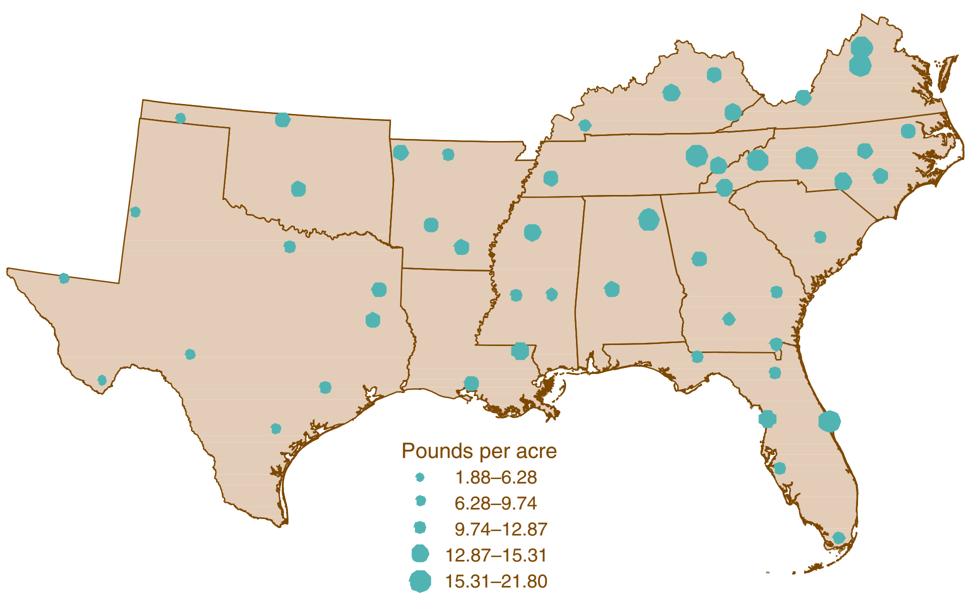

Figure 18.1—Current (1999) distribution of sulfate deposition in pounds per acre across the South (National Atmospheric Deposition Program 2000).

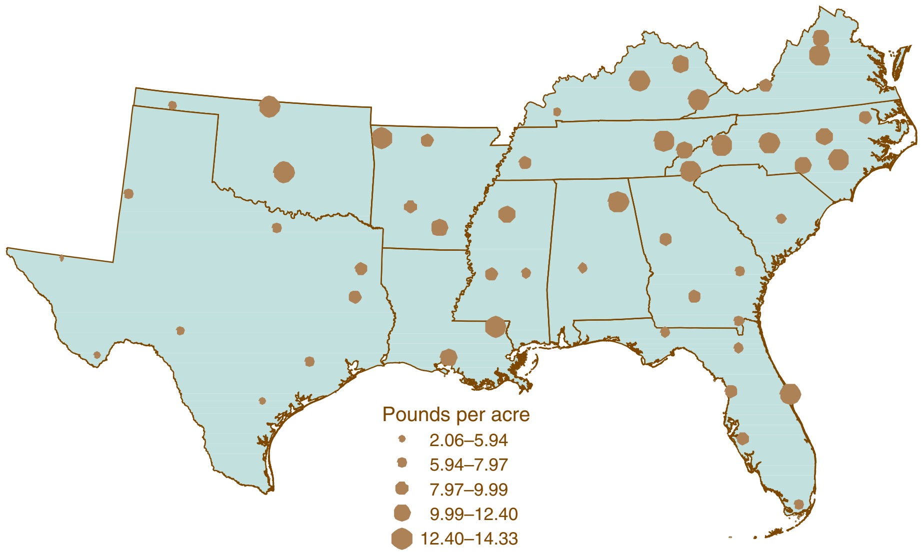

Figure 18.2—Current (1999) distribution of nitrogen deposition in pounds per acre across the South (National Atmospheric Deposition Program 2000).

nutrients and degradation because of their ability to buffer sulfur and nitrogen deposition. These forests generally have large calcium pools that increase their ability to buffer acid deposition.

There is a wide range of sulfate deposition rates across the South (National Atmospheric Deposition Program 2000) (fig. 18.1). The mean regional sulfate deposition for 1999 was 11 pounds per acre, which is a 13-percent decrease in sulfur deposition from 1994 (National Atmospheric Deposition Program 2000). The highest regional sulfur values are in North Carolina and Tennessee (fig. 18.1).

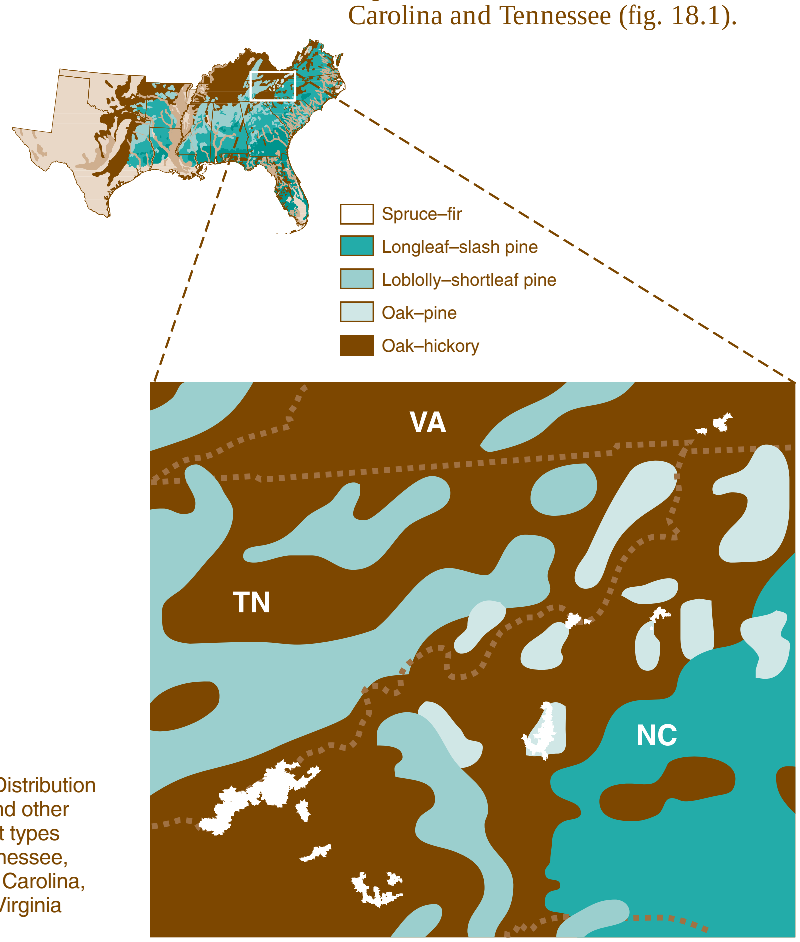

Figure 18.3—Distribution of spruce-fir and other southern forest types in eastern Tennessee, western North Carolina, and southern Virginia (Eyre 1980).

They are produced primarily in industrialized States in the northern part of the South.

Currently, forests in the South are exposed to a wide range of nitrogen deposition rates (National Atmospheric Deposition Program 2000) (fig. 18.2). The mean regional nitrogen deposition for 1999 was 10 pounds per acre, a 10-percent decrease in nitrogen deposition from 1994 (National Atmospheric Deposition Program 2000). The highest regional nitrogen values are generally located in the northern part of the South (fig. 18.2). Their sources are emissions from all 31 States east of the Mississippi River (Nash and others 1992).

For this discussion, the South has been divided into nine forest types according to various factors that include geographic location, precipitation, minimum and maximum air temperatures, and soil conditions (more or less sensitive to acid precipitation). Five of these forest types are shown in fig. 18.3. Sensitive soils have low base cation stores, and the ecosystem has a low ability to retain sulfur or nitrogen, or both. Less sensitive soils are ones with high concentrations of base cations, high buffering capacity to sulfur and nitrogen deposition, and, normally, nitrogen deficiency. Within the region, the high-elevation spruce-fir forests are most sensitive to sulfur and nitrogen deposition. The least sensitive ecoregions are those covered primarily by hardwood, pine, and oak-pine forests. The sensitivity of a given region to acid precipitation depends on the ability of the rocks and soils to neutralize or buffer the acid. Soils derived from granite, which are low in calcium, are highly sensitive. Soils derived from limestone, which are high in calcium, are much more capable of buffering the acid.

Acid Deposition Methodology: Future Predictions

Sulfur deposition is a primary contributor to acid deposition that indirectly affects forest decline by leaching base cations from the soil. Therefore, in 1990, Title IV of the Clean Air Act set as its primary goal the reduction of annual SO_2 emissions by 10 million tons below 1980 levels (U.S. Environmental Protection Agency 1997a). To achieve these reductions by

2010, the law invoked a restriction on power plants fired with fossil fuels. By 1995, nationwide emissions of SO_2 were reduced by almost 40 percent below their required level. In addition, monitoring sites throughout the United States found statistically significant reductions in precipitation acidity and sulfate concentrations (National Acid Precipitation Assessment Program 1998). Attempts to reduce nitrogen deposition were initiated in 1996. Although Title IV initiated a reduction in annual nitrogen deposition, new concentrations are expected to have potential impacts on forests across the South. Modeling future projections and impacts of nitrogen and sulfur deposition on forested ecosystems in the Southern Appalachian Mountains is an ongoing research objective of the Southern Appalachian Mountains Initiative (SAMI). The North Carolina General Assembly is reviewing a bill that would reduce nitrogen oxides and sulfur oxides generated by coal-powered utility plants by more than 70 percent (North Carolina General Assembly 2001). Governor Michael Easley supports this legislation and has begun to discuss regional air pollution reduction initiatives with lawmakers around the South (North Carolina Department of Environment and Natural Resources 2001).

Acid Deposition Data Sources

Primary data sources for sulfur and nitrogen deposition were the National Acid Deposition Program (National Acid Deposition Program 2000) and cited literature.

Acid Deposition Results

Although sulfur is an essential nutrient for soil and plant metabolic processes, sulfur deposition can contribute to degradation of soil chemistry (Reuss and Johnson 1986). Long-term increases in soil acidity resulting from sulfur deposition are believed to affect nutrient cycling by leaching nutrients, such as calcium and magnesium (Fenn and others 1998). Research has also shown that sulfur deposition provides the stimulus to mobilize aluminum in soil solutions (Reuss and Johnson 1986). Dissolved aluminum interferes with the uptake of calcium and other root functions (Johnson and others 1991).

Currently, high-elevation spruce-fir forests are the most susceptible to the effects of sulfur deposition (McLaughlin and Percy 1999) because they lack the ability to buffer sulfur deposition and are low in base cation pools. Future rates of sulfur deposition are expected to decrease, which could lead to a reduction in the effects of sulfur deposition on base cations in high-elevation spruce-fir forests. Recent evidence indicates that most Southern Appalachian soils supporting spruce-fir ecosystems are poorly buffered, high in aluminum, and nitrogen saturated (Johnson and others 1991). Nitrogen saturation occurs when ammonium (NH_4) and nitrate (NO_3) are present in quantities that exceed total combined plant and microbial demand. Excess levels of nitrogen have been found to affect soil and plant calcium:aluminum ratios (Johnson and others 1991), cause aluminum toxicity (Shortle and Smith 1988), and decrease calcium uptake and leaching of base cations (McLaughlin and others 1998) in these sensitive forests. A lack of calcium changes the wood structure of spruce and fir and may change the ability of branches to withstand stress (McLaughlin and others 1998). Furthermore, excess levels of nitrogen decrease the rates of some critical functions of soil microorganisms, including decay of forest floor material (Drohan and Sharpe 1997). These effects on forest soils are most dramatic in the sensitive soils under spruce-fir forests. Conversely, in an oak-pine forest in the North Carolina Piedmont, Johnson and others (1995) predict that forest floor nutrient contents will be virtually unaffected by a 50-percent reduction in sulfur deposition over the next 20 years.

Effects of acid deposition on tree growth have been associated with nutrient limitations caused by increases in soil aluminum concentrations. Studies of historical tree-ring chemistry (Bondietti and McLaughlin 1992) have shown that calcium concentrations in stemwood increased as growth increased during the late 1940s and 1950s. However, decreases in tree growth were associated with increases in aluminum:calcium ratios in the wood, suggesting that the availability of calcium was reduced at the same time aluminum concentrations increased. McLaughlin and Kohut (1992) have shown evidence for the competitive inhibition of calcium uptake by aluminum. Dendroecological- and plot-based data have shown declines in radial growth of red spruce (LeBlanc and others 1992) and canopy-crown deterioration during the mid-to-late 1980s in the Southern Appalachian Mountains (Peart and others 1992).

Whereas acid deposition has affected tree growth in spruce-fir forests of the Southern Appalachians (McLaughlin and others 1998), damage to these ecosystems is not limited to acid deposition. Reams and Van Deusen (1993) reported that stand disturbances and changes in stand dynamics have resulted in radial growth declines in spruce-fir forests. In addition, the balsam woolly adelgid was introduced into North America at the beginning of the 20th century, and the exotic insect has been active in the Southern Appalachians since the late 1950s (McLaughlin and others 1998). The damage to mature Fraser fir in the Southern Appalachians by the woolly adelgid has been extensive over the past 15 years (Dull and others 1988). Although heavy infestation is unquestionable evidence that the adelgid plays a major role in killing these trees (see chapter 17 for more details), it is also important to consider the influence of predisposing factors, including abiotic stressors such as acid deposition, on the susceptibility of forests to pathogens (Manion 1981).

Hardwood forests in the South are considered less sensitive to nitrogen deposition than spruce-fir forests because they still have adequate stores of base cation nutrients, and the soils still maintain considerable capacity to retain the deposited nitrogen (National Acid Precipitation Assessment Program 1998). In most hardwood forests, virtually all nitrogen deposition is either adsorbed in the soil or used by vegetation and microorganisms. Much of this nitrogen may be removed later by forest harvesting. These systems therefore have not shown negative effects from increases in nitrogen deposition and may respond with increased growth. Research has shown that 22.8 pounds per acre per year of nitrogen fertilizer increased basal area growth of trees by 67 percent (McNulty and Aber 1993).

Impacts of nitrogen deposition on forest health have not been detected in the pine and oak-pine forests of the South (National Acid Precipitation Assessment Program 1998). However, nitrogen is a major contributor to the depletion of base cations in many buffered soils supporting southern pine and oak-pine forests. Therefore, over the course of decades, nitrogen deposition is likely to reduce pine forest productivity (National Acid Precipitation Assessment Program 1998). Increases in growth are expected for some nitrogen deficient soils, whereas negative effects are expected to be limited to the most acidic soils.

In the future, nitrogen deposition will continue to impact the structure and function of high-elevation spruce-fir forests. In addition, some hardwood, pine, and oak-pine forests that are sensitive to nitrogen deposition could respond with reduced growth rates and accelerated tree mortality over the long term. However, research has predicted that in oak-pine forests in the North Carolina Piedmont, vegetation will respond positively to a 200-percent increase in nitrogen deposition over the next 20 years. A 3- to 9-percent increase in vegetation nutrient content and a 10- to 30-percent increase in forest floor nutrient content are expected (Johnson and others 1995).

Currently, the SAMI Class I Wilderness Areas are much more sensitive to acid precipitation than any other areas surveyed by the National Stream Survey (NSS) in the Southern Appalachians (Herlihy and others 1996). The wilderness areas of greatest concern are Otter Creek and Dolly Sods in West Virginia. There, the percentage of acidic stream length is high, pH is low, and sulfate and inorganic aluminum concentrations are high. Additionally, stream nitrate concentrations, an indicator of acid deposition effects, have been shown to have a strong correlation with forest age. The highest concentrations occur in old-growth forests, where biological demand for nitrogen is lowest. The wilderness area of least concern is the Sipsey in Alabama because sulfate concentrations are not increasing, and acid neutralizing capacity (ANC) of streams in this area is high.

ANC has been used to determine stream quality because stream acidification affects fish and other aquatic species. Research in the South has shown that the biological response of brook trout can be altered by ANC (table 18.1). Furthermore, the Southern Appalachian Assessment has shown that 70 percent of sampled streams have suffered moderate to severe fish community degradation, and about 50 percent of the stream miles in West Virginia and Virginia show habitat disruption (Southern Appalachian Man and the Biosphere 1996). However, streams targeted by the NSS in the southeastern highlands, (which includes the Ozarks/Ouachita, Piedmont, Southern Appalachians, Southern Blue Ridge, and ecological subregions in the States of Arkansas, Georgia, North Carolina, and Tennessee) appear to be buffered from sulfur deposition by a substantial amount of sulfate adsorption in watershed soils (Rochelle and Church 1987). As a result, sulfate concentrations in these streams are low.

Table 18.1—Acid neutralizing capacity (ANC) categories for brook trout response

μeq/L	Classification	Biological response
>50	Not acidic	Reproducing brook trout populations expected where habitat is suitable
20-50	Transitional	Extremely sensitive to acidification; brook trout response variable
0-20	Episodically acidic	Sublethal and/or lethal effects on brook trout likely
<0	Chronically acidic	Lethal effects on brook trout likely

Source: Bulger and others 1998.

Acid Deposition Discussion and Conclusions

Emissions of SO_2 and NO_x are decreasing. However, plant species structure and compositon, soil chemistry, and microbial activities continue to change. Currently, the mortality and decline of Fraser fir and red spruce at high elevations in the Southern Appalachians are the only cases of significant ecosystem damage. Thus, less than 5 percent of the South is currently being negatively impacted by elevated sulfur and nitrogen deposition (Fenn and others 1998). In addition, atmospheric deposition reduces the number of microorganisms important to nutrient cycling and removes important nutrients from the soil, making spruce-fir forests more susceptible to canopy deterioration, drought, loss of foliage, insects, and diseases. Hardwood, pine, and mixed oak-pine forests are less sensitive than spruce-fir for several reasons, including biological nitrogen demand, higher soil cation exchange capacity, and faster nitrogen cycling.

Since most hardwood, pine, and mixed forests are nitrogen deficient, they may experience increased growth rates in response to continued elevated nitrogen deposition. Conversely, nitrogen deposition can significantly degrade some of these forests over time (years to decades), especially in areas where nitrogen levels may be high and the soil has reached or is approaching saturation.

Sulfate and nitrate concentrations have increased in streams throughout the South, but not to levels that are considered regionally problematic. Furthermore, sulfate and nitrate in some streams are low or near detection limits (Swank and Vose 1997).

Acid Deposition Needs for Additional Research

To address the indirect impacts of nitrogen and sulfur deposition that lead to soil and vegetation degradation in high-elevation spruce-fir and hardwood forests, continued intensive monitoring, modeling, and validating of acid deposition and nutrient cycling processes must occur across local and regional scales. Monitoring efforts should be supplemented with long-term regional experiments (greater than 5 years) in which realistic acid deposition effects on soil chemical properties and stream quality are evaluated (McNulty and others 1996).

Ozone

Ozone Methodology: Current Conditions

Ground level O_3 is created through a complex series of atmospheric chemical reactions involving NO_x and volatile organic compounds (VOC) in the presence of specific climatic and weather conditions (Chameides and Lodge 1992). Ozone exposure levels are influenced by factors such as temperature, time of day, relative humidity, wind speed, wind direction, and spatial proximity of anthropogenic and biogenic emission sources (Schichtel and Husar 1999). Ozone can reduce foliage, stem, and root growth in trees by impacting leaf-cell photosynthesis and gas exchange.

Allen and Gholz (1996) revealed extensive spatial and temporal variation in O_3 concentrations across the region. For at least two reasons, accurate prediction of annual variability in O_3 levels for forested areas has not yet been achieved: (1) monitoring sites in rural, forested areas are lacking; and (2) modeling O_3 exposure is very difficult because of weather and human-related conditions that contribute to its annual variability (Allen and Gholz 1996). However, annual variation in O_3 at select monitoring sites has been analyzed.

Annual O_3 variability for the United States can be seen in figure 18.4, which shows 3-month maximum daily SUM06 O_3 exposure levels for 1988 through 1992. A SUM06 value is the sum of all mean hourly daytime O_3 concentrations that are at least 0.06 parts per million (ppm) over a continuous 3-month period (92 days) during the summer. The SUM06 exposure index represents the threshold ambient O_3 level (0.06 ppm-hours) below which many forms of vegetation can resist harmful cumulative O_3 effects. The SUM06 index may be particularly useful because negative effects of O_3 exposure, especially on tree photosynthetic capacity (Richardson and others 1992) and foliage production and retention (Kress and others 1992), may be cumulative and linear, extending over multiple growing seasons.

Ozone Methodology: Future Predictions

Over the past century, industrial activity and automobile emissions have increased the atmospheric concentrations of O_3 precursors. As a result, typical ambient O_3 concentrations have increased from 0.02-0.04 to 0.04-0.06 ppm—a trend that is expected to continue into the 21st century (National Academy of Science 1992). Assuming a 1- to 2-percent annual increase in tropospheric O_3, as estimated by Fishman (1991), the United States would achieve a 50-percent increase in ambient O_3 in 21 (base 1990) years and a doubling of O_3 concentrations in 35 years. The National Academy of Science (1992) estimated an increase of 40 percent by the year 2020. Thompson (1992) used several computer models to predict that O_3 concentrations will rise by 0.5 percent per year for the next 50 years, whereas Chameides and others (1994) suggested that the frequency of O_3 events with concentrations high enough to damage plants will triple over the next 30 years. However, more recent ozone modeling efforts by SAMI predicted a 10- to 15-percent reduction in maximum daily ozone levels between 1995 and 2010 for the Southern Appalachians based on current emissions controls (Southern Appalachian Mountains Initiative 2001).

Ozone Data Sources

Ozone monitoring studies have identified different O_3 exposure profiles at high elevations (greater than 4,900 feet) than at lower elevations (less than 1,600 feet) and near sea level (Aneja and others 1994). Levels of O_3 in mountains are lower than in lowlands during the daytime. Near sea level, O_3 levels are very high during the day, often exhibiting a distribution characteristic of the peak hours for automobile traffic. The concentrations in the mountainous areas of the South have important implications for forest health. The ambient O_3 concentrations are sufficiently high to induce injury to sensitive native vegetation in the Blue Ridge Mountains (Skelly and Hildebrand 1995). In addition, some areas in the region are downwind of significant NO_x and VOC emission sources. For example, regionally high O_3 levels found in the Blue Ridge Mountains and Shenandoah Valley of Virginia result from a combination of upwind emission sources located in the industrial Midwest and specific weather patterns (Wolff and others 1977). These weather-related O_3 episodes may be attributed to a combination of local- and regional-scale factors: (1) higher than normal ambient temperatures, (2) wind speeds and directions associated with stationary high-pressure systems that produce local air stagnation, and (3) lower than normal relative humidity (Aneja and Li 1990).

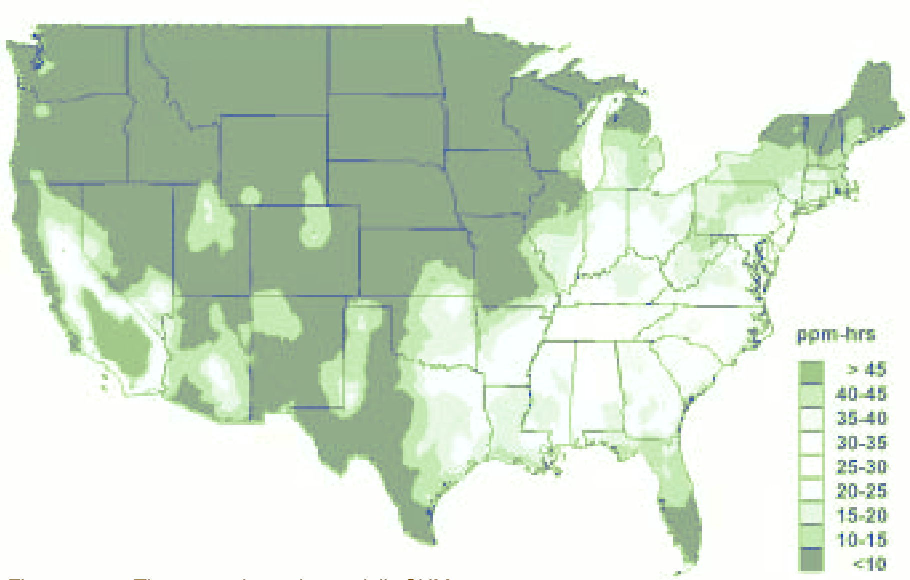

Figure 18.4—Three-month maximum daily SUM06 ozone exposure grid for 1990 showing spatial variability in ozone concentrations. The exposure grid was calculated by U.S. Environmental Protection Agency using NHEERL-WED's Geographic Information System model to spatially interpolate SUM06 values calculated from the AIRS monitoring network (Schichtel and others 1996).

Ozone Results

To cause tree damage, O_3 must be absorbed by the plant through the stomatal openings found on the surface of leaves in a process known as stomatal conductance. Stomates open during daylight hours to permit the exchange of gaseous compounds (CO_2, O_2, and water vapor) necessary for photosynthesis. At night, stomates close, preventing the transpiration of water. Because stomates are open during the day, daytime O_3 concentrations are most likely to damage trees. Rates of stomatal conductance vary by species and age, and these rates directly determine both the quantity of O_3 uptake and the plant's response to a given concentration of O_3 (Kelly and others 1995). In general, ozone-sensitive tree species under high O_3 stress experience reduced leaf area, slower growth during drought conditions, and lower vertical growth rates (Southern Appalachian Mountains Initiative 2001).

It appears that O_3 affects growth and vitality indirectly by predisposing trees to injury from other biotic and abiotic stressors (Chappelka and Freer-Smith 1995). For example, ponderosa pine exhibits increased sensitivity to bark beetle attack in the San Bernardino Mountains following O_3 damage (Cobb and others 1968). In the South, pines typically do not show visible symptoms of O_3 injury under ambient O_3 conditions (Berrang and others 1996) except during extended periods of high O_3 levels when injury is readily visible.

The amount and way that O_3 affects trees depend on the age of the trees and the species. Given similar amounts of O_3 exposure, immature hardwoods generally exhibit more growth loss than softwoods (table 18.2) (McLaughlin and Percy 1999). Based on the limited number of studies available, mature hardwood growth rates appear to be more sensitive to O_3 exposure than mature softwood growth rates (table 18.2). According to Dougherty and others (1992), an average mature loblolly pine tree growing in a plantation experiences a 3-percent annual loss of gross primary production under ambient O_3 conditions in the South. In a review of 19 studies measuring the influence of O_3 exposure on growth of slash pine, shortleaf pine, and loblolly pine seedlings and saplings, Teskey (1996) concluded that annual growth reductions for pine seedlings in the South were between 2 and 5 percent. For mature loblolly pines, Dougherty and others (1992) used a process model to estimate annual growth reductions of about 3 percent under ambient O_3 concentrations.

Hogsett and others (1997) found that black cherry has strong O_3 sensitivity, and tulip poplar has moderate O_3 sensitivity. Southern yellow pine species showed little response to changes in SUM06 O_3 concentrations, and sugar maple exhibited a threshold response in which annual biomass increased dramatically between 26 and 38 ppm-hour per year SUM06.

Overall, it appears that the growth of mature southern yellow pines is being reduced by current typical ambient O_3 levels at annual rates that vary from 0 to 10 percent per year. Annual growth reductions for pine seedlings in the South are probably between 2 and 5 percent (Teskey 1996). However, at present there are no indications of community level changes (competition dynamics, community structure, and function, etc.) attributable to O_3 (McLaughlin and Percy 1999). Although O_3 may be reducing annual growth of trees in the South, other air-borne chemicals such as CO_2 and nitrogen and sulfur compounds may be simultaneously increasing growth (Teskey 1996), thereby effectively masking the negative effects of O_3 on overall forest health.

Ozone Discussion and Conclusions

The growth impacts of ambient O_3 levels on southern pines appear to be statistically significant at this time (McLaughlin and Percy 1999, Teskey 1996). Additional increases in tropospheric O_3 will almost certainly have negative impacts on the growth of pine species in the South (Southern Appalachian Mountains Initiative 2001, Teskey 1996).

Another important consideration for future forest health is the frequency and intensity of forest fires. Forest fires produce carbon monoxide (NO_x) and gaseous hydrocarbons that are the precursors of atmospheric O_3 (Bohm 1992). Therefore, forest fires may contribute to O_3 production in wilderness and rural areas (Bohm 1992). Bohm (1992) observed that O_3 has been found to accumulate near the location of a burn, and substantial increases in O_3 concentrations (greater than 50 percent above ambient) have been detected downwind of burned areas and at the top of burn plumes.

The important relationship between soil moisture, stomatal conductance, and tree sensitivity to O_3 levels highlights the importance of climate in predicting future impacts of O_3 on forest health. Under future climate scenarios, trees in areas of the South characterized by periods of persistent drought and poor soil water storage capacity will be more sensitive to O_3 pollution and will likely incur substantial visible foliar damage (Maier-Maercker 1999) and growth reductions (Southern Appalachian Mountains Initiative 2001).

Ozone Needs for Additional Research

Because expert predictions identify O_3 as a significant forest stressor well into the 21st century (Heck and others 1998), scientists and policy experts have jointly assessed critical research needs pertaining to effects on forested systems. The Ecological Research Needs Workshop (U.S. Environmental Protection Agency 1998) developed one such set of research priorities. A summary of those priorities for forests and natural areas is provided here (Heck and others 1998):

1. Consideration of factors related to scaling results in growth chambers to mature trees, stands, communities, and landscapes.

2. Measurement of selected endpoints (growth, mortality, foliage injury, etc.) in managed and natural ecosystems such as loblolly pine plantations or bottomland hardwood ecosystems across selected O_3 gradients throughout the South, using results to support development of empirical and process-based models designed to understand the mechanisms of plant response to O_3.

3. Determination of utility of using visible foliar injury and other biological indicators to interpret effects of O_3 on specific indices of ecosystem health.

4. Development of economic techniques that measure changes in the value of managed and natural ecosystems affected by O_3.

5. Development of a reasonable O_3 exposure index via defined relationship

Table 18.2— Estimates of ambient O_3 effects on growth of forest tree species occurring in the South

Species	Growth reduction	Conditions	Source
	Percent		
		Seedling/sapling studies	
Multiple species	0-10	Shoot growth	Chappelka and Samuelson 1998
Southern pines	2- 5	Summary estimate of 19 field-chamber studies	Teskey 1996
Loblolly pine	0- 3	Mean response to 50-200 ppm-hr	Taylor 1994
	1-10	Sensitive family response to 50-200 ppm-hr	(synthesis-whole tree biomass)
Hardwoods	13	Values derived from response	Reich and others 1988
Conifers	3	surface at 20 ppm-hr	
Black cherry	10-24		Hogsett and others 1997
Yellow-poplar	5-13	Values derived from O_3 exposure-	
Sugar maple	0- 9	response functions and model-	
Red maple	0- 1	simulated tree and stand	
Loblolly pine	2- 5	response[a]	
Eastern white pine	4- 8		
Virginia pine	0- 1		
		Mature tree studies	
Loblolly pine	2- 9	Whole tree carbon model using branch chamber data (GA)	Dougherty and others 1992
	3	Mean response	
	0-13	Mean annual weekly responses to O_3 and interactions of O_3 and moisture stress, 5 years (TN)	McLaughlin and Downing 1996
	0- 5	Annual O_3 effect—no water stress	
	0-30	Annual O_3 effect—moderate water stress	
Hardwoods	3-16	Regional simulation with canopy-stand model across moisture gradients. Highest reductions occurred in areas with highest O_3 levels and on soils with high water holding capacity where drought stress was absent.	Ollinger and others 1997

[a] Percent reduction in annual net primary production.
Source: McLaughlin and Percy (1999), with additions provided.

HEALTH

between O_3 exposure concentration, uptake dose, and selected endpoints (growth, mortality, foliar injury).

6. Study of the interactions between O_3 and other abiotic or biotic stressors.

Climate Change and Extreme Weather-Related Events

Extreme Weather-Related Event Methodology: Current Conditions

Climate effects on forest conditions are most strongly expressed by extreme events such as fire, hurricanes, tornadoes, floods, drought, and ice storms (Dale and others 2000). Each type of event affects forests differently; some cause large-scale tree mortality, whereas others, such as ice storms, impact community structure and organization without causing massive mortality.

Wildfire—The frequency, seasonality, size, intensity, and type of wildfires depend on weather phenomena and forest structure and composition. Fire initiation and spread also depend on fuel availability, the presence of ignition agents, and topography.

Across the southern Coastal Plain, forest shrub and brush species can create highly flammable fuel conditions in just 5 years under the right climatic conditions if fuel loads are not managed. Therefore, fuel management is necessary. Each year, across all land ownership classes, 5.4 million acres are managed with prescribed fire. Seventy-five percent of the prescribed burning occurs in the States of Alabama, Florida, and Georgia. All 34 national forests in the region have prescribed fire programs, and, since 1944, approximately 21 million acres have been treated to minimize wildfire risk (Forest Health Protection Program 2000). Fire management would be more prevalent were it not for smoke problems associated with controlled burns. Criteria included in the U.S. Environmental Protection Agency's National Ambient Air Quality Standards for Particulate Matter (U.S. Environmental Protection Agency 1997b) limit the amount and extent of prescribed fire programs because smoke can impair road visibility and breathing in sensitive individuals.

Wildfire can substantially influence forest structure and function. Ecological effects of forest fires include mortality of individual trees, shifts in successional direction, induced seed germination, acceleration of nutrient cycling, death of seeds stored in the soil, changes in surface soil organic layers and underground plant root and reproductive tissues, volatilization of soil nutrients, and increased landscape heterogeneity (Whelan 1995). As a result of these effects, the capacity of forests to provide wildlife habitat, timber, and recreation may be diminished (Flannigan and others 2000).

Hurricanes—Hurricanes disturb forests along the coastlines of the South. Ocean temperatures and regional weather influence the path, size, frequency, and intensity of hurricanes (Emanuel 1987). An average of two hurricanes strike land every 3 years in the United States (Hebert and others 1997). Some scientists have hypothesized that hurricane impacts on forests, including mortality, may be related to soil characteristics (Duever and McCollum 1993).

Tornadoes—Tornadoes are one of the most important agents of abiotic disturbance in eastern deciduous forests. Nearly 1,000 tornadoes occur each year in the conterminous United States (Peterson 2000). In the South, tornadoes are very common in Oklahoma and Texas and frequent in Alabama, Florida, Louisiana, and Mississippi. Tornadoes can cause severe mortality, reduce tree density, alter stand-size structure, and modify local environmental conditions via soil erosion or nutrient loss (Dale and others 2000). The resulting disturbance may bring about the release of advance regeneration, seed germination, or accelerated seedling growth (Peterson and Pickett 1995). These effects can change gap dynamics, successional patterns, and other ecosystem level processes such as water use. The relationship between wind strength and severity of disturbance varies by tree species and forest type. Shallow-rooted species and thinned stands tend to be more vulnerable, but multiple factors influence tree response to windstorms.

Floods—Floods occur throughout the South but are most concentrated in coastal and floodplain areas. On average, floods cause almost $4 billion dollars in damage each year (National Oceanic and Atmospheric Administration 2000). Upland forest ecosystems that experience flooding respond with reduced photosynthetic rates; over extended periods, changes in tree species composition are possible, as some species are more flood tolerant that others (Burke and others 1999, Iles 1993). Most trees can withstand 1 to 4 months of flooding duration without significant injury (Bratkovich and others 1993). In extreme situations, higher mortality rates may occur (Iles 1993). Anaerobic soil conditions in flooded areas cause physiological stress and influence nutrient availability (Burke and others 1999). Secondary effects of flooding include elevated soil erosion and sedimentation rates (Iles 1993). At the regional scale, there is high variability in the spatial location and amount of disturbance associated with floods.

Drought—Droughts occur in most forest ecosystems in the South. Occurrence is irregular in forests east of the Mississippi River, occasional across most of the South, and more common in late summer on the Coastal Plain (Hanson and Weltzin 2000). Consequences of long-term drought or flooding are generally proportional to the area affected; during the past few decades, an increasing portion of the United States has experienced either severe drought or flooding (Karl and others 1995c). Drought effects are influenced by soil texture and depth, exposure, species composition, life stage, and the frequency, duration, and severity of drought. The immediate response of forests to drought is to reduce water use and growth. Small plants, including seedlings and saplings, are usually the first to succumb to moderate drought conditions. Deep rooting and stored carbohydrates and nutrients make large trees susceptible only to severe droughts (Dale and others 2001).

Ice Storms—Ice storms occur throughout the South. They are produced when rain falls through subfreezing air masses, freezing when contact is made with objects on the ground. Ice accumulation varies with topography, elevation, and area of exposure. Ice storms may sever twigs and bend or break stems, causing moderate crown loss. Damage to forest stands can range from light and patchy to the breaking of all mature stems, depending on stand composition, past disturbances, and the amount of ice accumulation (Irland 2000). Effects of ice storms on forest stands include stem damage, loss of growth until leaf area is restored, and possible shifts in tree species composition toward trees more resistant to ice damage.

Recently thinned stands may have increased vulnerability to ice storm damage because tree crowns have spread into openings, but branch strength has not yet increased. Potentially, there are several secondary consequences of ice damage. Susceptibility to insects and diseases may be increased, and fuel loads may accrue, heightening wildfire risk in some areas (Irland 2000).

Climate Change Methodology: Future Predictions

The effects of climate change on southern forest productivity and hydrology across a range of climate and site conditions were assessed with the well-validated, physiologically based forest process model PnET-II (McNulty and others 2000). PnET-II used four monthly climate variables (minimum air temperature, maximum air temperature, precipitation, and solar radiation), forest-type-specific vegetation parameters, and site-specific soil water holding capacity to predict forest growth and drainage across the South at a 0.5- by 0.5-degree (approximately 30- by 30-mile) spatial resolution. Atmospheric CO_2 increases were incorporated into PnET-II by entering the relationship between water use efficiency (WUE) and CO_2 level. PnET-II results for pine and hardwood forest types have been validated for the South (McNulty and others 2000).

Impacts of climate change on forest area, distribution, and biodiversity were studied with biogeography models. This type of model uses resource and ecophysiological constraints such as available soil water and minimum winter temperatures to simulate climate change impacts on forest ecosystems at regional, continental, and global scales (Bachelet and Neilson 2000). The biogeography models used here predict the dominance of different plant species under different climatic and environmental scenarios. The several biogeography models used for this Assessment included the Mapped Atmosphere Plant Soil System (MAPSS), BIOME3, and MC1 (Bachelet and Neilson 2000, Bachelet and others 2001). Input datasets include latitude, mean monthly temperature, wind speed, solar radiation, and soil properties such as texture and depth. All of these models project vegetation responses to changes in CO_2 but through different mechanisms.

Climate Change and Extreme Weather-Related Event Data Sources

To date, it is generally believed that hotter and more variable air temperatures will occur across the United States in the future (National Assessment Synthesis Team 2001). However, the timing and distribution of precipitation or other weather phenomena are much less certain (Dale and others 2000). The transient climate change scenarios used for this Assessment do not adequately represent extreme events because of their coarse spatial and temporal resolution (monthly time step, approximately 1,000 square miles) (National Assessment Synthesis Team 2001). Extreme events may last only minutes or days, and their extents may range from local to small regional scales. When the effects of extreme events are averaged over large periods of time and space, much information is lost. Therefore, very little quantitative data on extreme weather events are available to predict future forest impacts. Instead, we will discuss the potential impact of projected general trends in extreme weather events on forest structure and function.

Two climate datasets developed by the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP) were used with the PnET-II model to assess future climate impacts on southern forest growth. The Historical Climate Series includes monthly and daily climate data with interannual variability for the conterminous United States from 1895 to 1993 (National Assessment Synthesis Team 2001). The Hadley Centre HadCM2Sul transient climate change scenario was used to represent climate variables from 1994 to 2100; other climate scenarios exist but were not available at the time of this analysis. For the continental United States, the HadCM2Sul scenario includes a relatively modest 2.8° average increase in air temperature, a 20-percent average increase in precipitation, and effects of doubled CO_2 and altered sulfate aerosol concentrations (based on IPCC projections of future greenhouse gases) by 2100 (Bachelet and others 2001). The mean temperature increase for the South is about 1.0° by 2030 and 2.3° by 2100; this degree of warming is smaller than that of any other region (National Assessment Synthesis Team 2001). This scenario predicts that the South will remain the wettest region for the next century; mean annual precipitation increase will be about 3 percent by 2030 and 20 percent by 2100. Other regions in the Eastern United States are predicted to experience similar increases in precipitation (National Assessment Synthesis Team 2001).

Predictions of forest area, distribution, and biodiversity used four equilibrium (UKMO, GISS, GFDL-R30, OSU) and three transient (HadCM2Sul, HadCM2GHG, CGCM1) climate scenarios as input for the MAPSS biogeography and MC1 dynamic global vegetation models. The range in temperature increase is 2.8 to 6.6° for all scenarios, with changes in precipitation varying greatly between the scenarios, and changes in CO_2 transient (as with HadCM2Sul) or instantaneously doubling in the case of the equilibrium scenarios. MC1 used only HadCM2Sul and CGCM1, whereas MAPSS used all equilibrium scenarios and averaged the last 30 years of the transient scenarios so they could be treated as equilibria. The BIOME3 model used only the transient climate scenarios (Bachelet and Neilson 2000).

Climate Change and Extreme Weather-Related Event Results

Wildfire—Because climate change may alter the frequency, intensity, distribution, or extent of wildfires, species regeneration patterns may be disturbed with species or communities at the edges of their natural range experiencing potentially severe effects.

Model results from the fire distribution module of MC1 predict great variation in future fire-weather patterns for the northern portion of North America (Bachelet and Neilson

2000). The seasonal severity rating (SSR) of fire hazard increases over much of North America under both the HadCM2Sul and the CGCM1 scenarios. The wetter HadCM2Sul scenario predicts smaller (less than 10 percent) increases in SSR by 2060 for most of the United States. The warmer and drier CGCM1 scenario produces a 30-percent increase in SSR for the South. Expected increases in area burned in the Unites States are between 25 and 50 percent by 2060, with most of the increase occurring across the South and in Alaska (Flannigan and others 2000).

In addition, recent results from the MC1 model, described by Neilson and Drapek (1998), show increases in biomass burned. This model includes an interaction with CO_2 and increased WUE that produces more biomass and thus more fuel, contributing to more and larger fires under a highly variable climate having dry years interspersed with wet periods.

Hurricanes—Global climate change may speed up the hydrologic cycle by evaporating more water, transporting that water vapor to higher latitudes, and producing more intense and possibly more frequent storms (Royer and others 1998, Walsh and Pittock 1998). Hurricane formation could be influenced by changes in temperature and the global hydrologic cycle, but neither the magnitude nor direction of the change can be predicted at this time. Sea-surface temperatures (SSTs) are predicted to increase, with warmer SSTs expanding to higher latitudes (Royer and others 1998, Walsh and Pittock 1998). Even if hurricane frequency does not increase, the intensity and duration of storms may increase with air and ocean temperatures, which are energy sources for hurricanes (Walsh and Pittock 1998).

Tornadoes—Berz (1993) suggested that the frequency and intensity of tornadoes (and hailstorms) might be accelerated with increased intensity of atmospheric convective processes. Karl and others (1995b) found that the proportion of precipitation occurring in extreme thunderstorms has increased in the United States from 1910 to 1990, and their research suggested that precipitation and temperature anomalies have become extreme in recent decades (Karl and others 1995a). The thunderstorm conditions that contribute to tornado formation have increased, and this trend is expected to continue with projected changes in climate. It can be inferred from this relationship that warmer temperatures will increase tornado frequency. Despite the data on thunderstorms and the indirect inferences about tornado frequencies, the understanding of tornado genesis is still inadequate for forecasting climate change impacts on tornado frequency or severity in the coming decades.

Floods—Climate change predictions include increased frequency of heavy precipitation events and severe flooding (Intergovernmental Panel on Climate Change 1998). From 1987 to 1997, there were 10 times as many catastrophic floods globally than in the previous decade (Hileman 1997).

Over the last century, sea level has risen 3 to 10 inches. Predicted increases in global air temperatures may result in sea level rises of 15 to 25 inches by 2100 (Gornitz 2001). Current trends in sea level have been confirmed to be higher than those found in long-term geologic records (Gornitz 2001).

Drought—Global circulation model predictions of future precipitation patterns are particularly problematic for the South. Although the HadCM2Sul scenario predicts increased precipitation throughout the United States, a Canadian Centre for Climate Modelling and Analysis GCM, CGCM1, predicts significant reductions in both summer and winter precipitation across the South by 2100. To address the potential impacts of drought on forests, the net effect of precipitation changes on soil water must be understood; unfortunately, global scale climate models are not designed to predict this information (Hanson and Weltzin 2000).

Ice Storms—Unfortunately, there is no consistent historic record of ice storms over broad scales with rigorous measurements of ice accumulation. Neither are historical data on climatology associated with ice storms sufficient to correlate past storm frequency and severity with past climate changes. Effects of future climate change on location, extent, and impacts of ice storms are therefore also unknown (Irland 2000).

Climate change—Southern forest productivity, as predicted by the PnET-II model and the HadCM2Sul climate scenario, is shown in figures 18.5, 18.6, and 18.7 for the decades centered on 2000, 2040, and 2090. Predicted productivity increased by 12 percent from 2000 to 2100 (National Assessment Synthesis Team 2001). Changes in forest productivity resulting from climate change were different for hardwood and pine forest types. By 2040, hardwood and mixed pine-hardwood forest productivity increased by 22 percent, whereas plantation pine forest productivity increased by 11 percent. By 2100, hardwood and mixed pine-hardwood forest productivity increased by 25 percent, and plantation pine forest productivity increased by 8 percent (National Assessment Synthesis

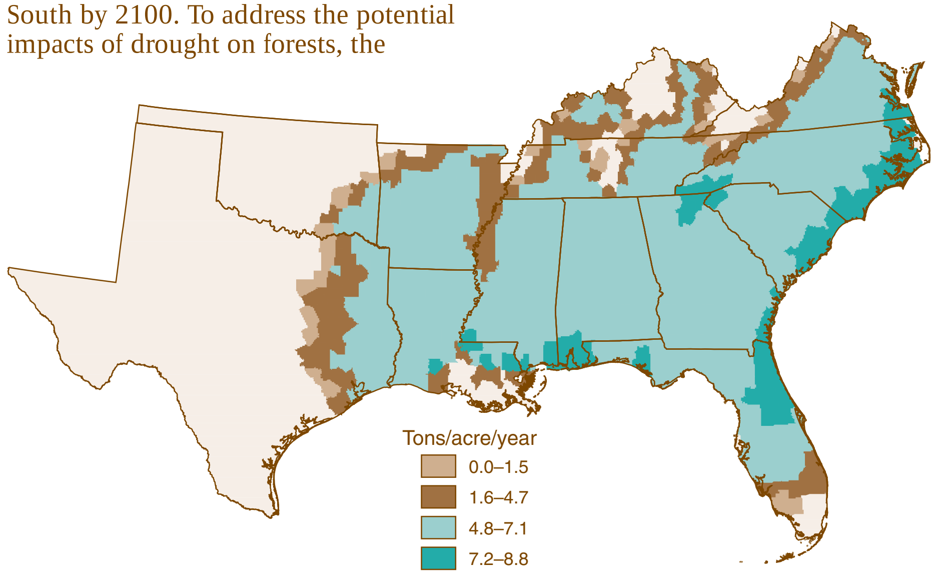

Figure 18.5—PnET-II model predictions of total potential annual southern forest growth, represented as net primary productivity and averaged for the decade centered on 2000 [National Assessment Synthesis Team 2001 (modified)].

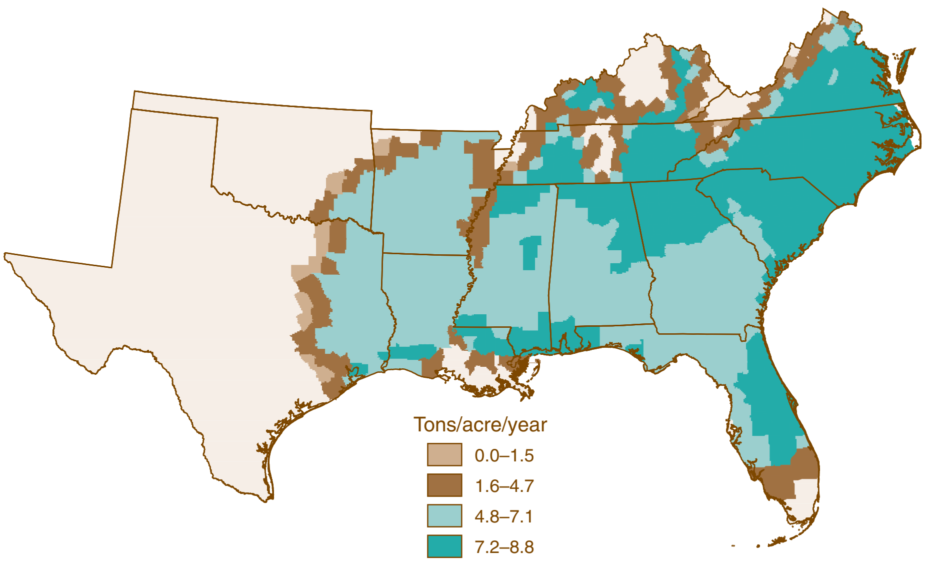

Figure 18.6—PnET-II model predictions of total potential annual southern forest growth, represented as net primary productivity and averaged for the decade centered on 2040 [National Assessment Synthesis Team 2001 (modified)].

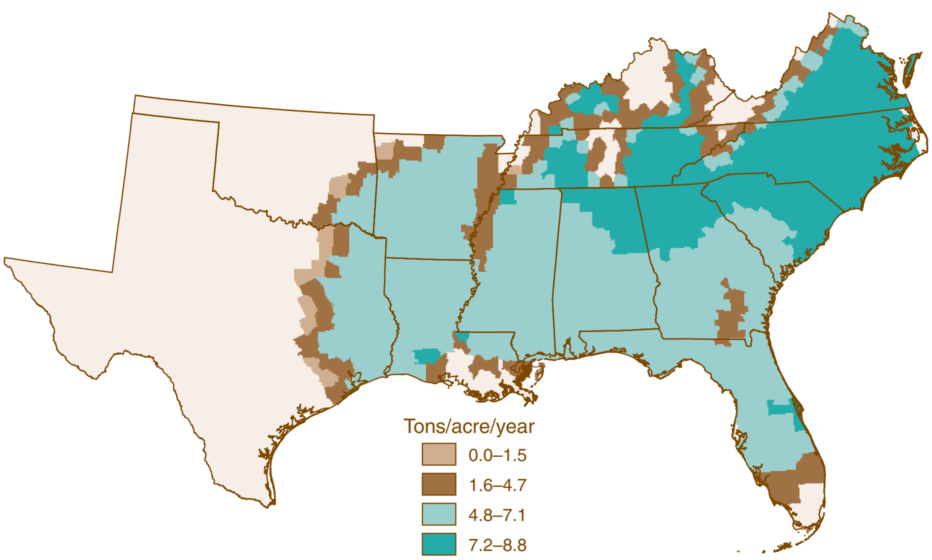

Figure 18.7—PnET-II model predictions of total potential annual southern forest growth, represented as net primary productivity and averaged for the decade centered on 2090 [National Assessment Synthesis Team 2001 (modified)].

Team 2001). A review of over 50 studies found an average increase in plant dry mass of 32 percent under a doubling of CO_2 concentrations. WUE, examined in another review, increased between 30 and 40 percent (Intergovernmental Panel on Climate Change 1998).

Both MAPSS and MC1 models predict that moderate temperature increases produce increased vegetation density and carbon sequestration across most of the United States with small changes in vegetation types resulting. If temperature increases are more severe, the models predict shifts in vegetation types and reductions in carbon storage. The South is predicted to have expanded forest area (national average of 20 percent) under the more moderate climate scenarios but forest decline under more severe climate scenarios (including CGCM1), with catastrophic fires potentially causing rapid vegetation conversion from forest to savanna (fig. 18.8) (Bachelet and others 2001). MC1 predicts a return to forest by the end of the 21st century, albeit with lower forest biomass than before the fires occurred. The same moderate-increase, severe-decrease trend is true for leaf area index (LAI), a measure of leaf area per unit of ground area, and vegetation density of forests in the South. MAPSS and MC1 predict an increased presence of tropical forests along the gulf coast (Bachelet and others 2001).

Climate Change and Extreme Weather-Related Event Discussion and Conclusions

Wildfire—The rapid response of fire regimes to changes in climate can potentially overshadow the direct effects of climate change on species distribution, migration, or extinction (Flannigan and others 2000, Stocks and others 1998).

Hurricanes—The effects of hurricanes on forest vegetation include sudden, massive, and complex patterns of tree mortality and altered patterns of forest regeneration (Lugo and Scatena 1996). A likely result is lower aboveground biomass in mature stands (Lugo and Scatena 1995). Faster rates of decomposition and vegetation regrowth have been measured after hurricanes; species substitutions, with those species having faster nutrient and biomass turnover rates becoming more competitive, may result (Lugo 2000). Hurricanes can also bury vegetation in carbon sinks, increasing belowground carbon storage (Dale and others 2000, Lugo 2000). Overall, it has been suggested that the decadal variation in hurricane intensity and frequency may be great enough to mask any changes resulting from climate change (Lugo 2000).

Tornadoes—Damage resulting from tornadoes may shift forest species composition towards late-successional species, as early successional species often are large and shallow rooted, making individuals more vulnerable. Because late-successional species may share these traits, effects of tornadoes or other catastrophic winds on species composition may be more contingent on forest species and size characteristics (Peterson 2000). Wind disturbances often remove dominant trees from the forest, changing species richness or evenness and potentially altering species diversity (Peterson 2000).

Floods—It is difficult to translate changes in precipitation patterns to effects on flood probability or severity. Existing flood records suggest that monitoring runoff and stream-flow levels may provide more insight on future floods (Intergovernmental Panel on Climate Change 1998).

At predicted levels of increase, sea level rise would threaten coastal areas with more frequent flooding, salinization of coastal streams and aquifers, and increased beach erosion. It is important to consider that local sea levels are also affected by regional processes such as ocean tides and currents (Gornitz 2001).

Drought—Secondary effects of drought may occur. When reductions in growth are extreme or sustained over multiple growing seasons, increased susceptibility to insects or disease is possible, especially in dense stands (Negron 1998). Drought may also reduce decomposition rates, leading to a buildup of organic matter on the forest floor. This buildup may reduce nutrient cycling or increase fire frequency or intensity.

The consequences of drought depend on annual and seasonal climate changes and the ability of current drought adaptations to provide resistance or resilience to new conditions. Forests are likely to grow to a level of maximum leaf area, using nearly all the available soil water in the growing season (Neilson and Drapek 1998). A significant increase in growing season temperatures could increase evaporation and trigger moisture stress.

If changes in regional precipitation reduce soil moisture, there may be direct impacts on plant foliage water status that modify carbon assimilation (Hanson and Weltzin 2000).

Overall, reductions in total annual rainfall would not increase drought severity in most forests of the South because early season rainfall is the most important determinant of total growth (Hanson and Weltzin 2000). However, there are different responses to late-season drought for hardwoods and pines of the Eastern United States. Hardwood growth activity does not overlap with drought occurrence, and therefore basal area growth is relatively unaffected. Because conifer stems grow during a greater portion of the growing season, their drought susceptibility is greater (Hanson and Weltzin 2000).

Ice Storms—Though the weather conditions producing ice storms are well understood, it is uncertain how climate change will influence the frequency, location, extent, or intensity of these extreme weather events. Jagger and others (1999) state that warmer winter temperatures brought about by climate change may increase the probability of ice storms across portions of the United States. Continued atmospheric warming will likely shift the distribution of ice storms northward, potentially decreasing the frequency and severity of ice storm damage to southern forests (Dale and others 2000, Irland 2000).

Climate change—According to the PnET-II and HadCM2Sul predictions, forest productivity increased more for hardwood and mixed pine-hardwood forest types than for pine plantations. The primary reason for this conclusion is the greater annual water demands of pine forest types. Even with increasing WUE resulting from increasing atmospheric CO_2, evapotranspiration rates increase with air temperature, and pines are still water limited under the HadCM2Sul climate scenario. Sensitivity analyses completed for PnET-II and the HadCM2Sul scenario showed that substantial variation in temperature increase might lead to larger net losses in forest area and productivity (National Assessment Synthesis Team 2001).

Elevated CO_2 influences tree physiology, potentially increasing productivity, WUE, and nutrient- (nitrogen) use efficiency. Reviews of CO_2-enrichment studies have shown positive but variable biomass accumulation. Interactions between CO_2 and other environmental factors account for some of the wide response range (National Assessment Synthesis Team 2001). For example, in a recent North Carolina field experiment, growth of loblolly pine increased by 25 percent under continuous CO_2 elevation (National Assessment Synthesis Team 2001). Maintaining such responses on a decadal time scale

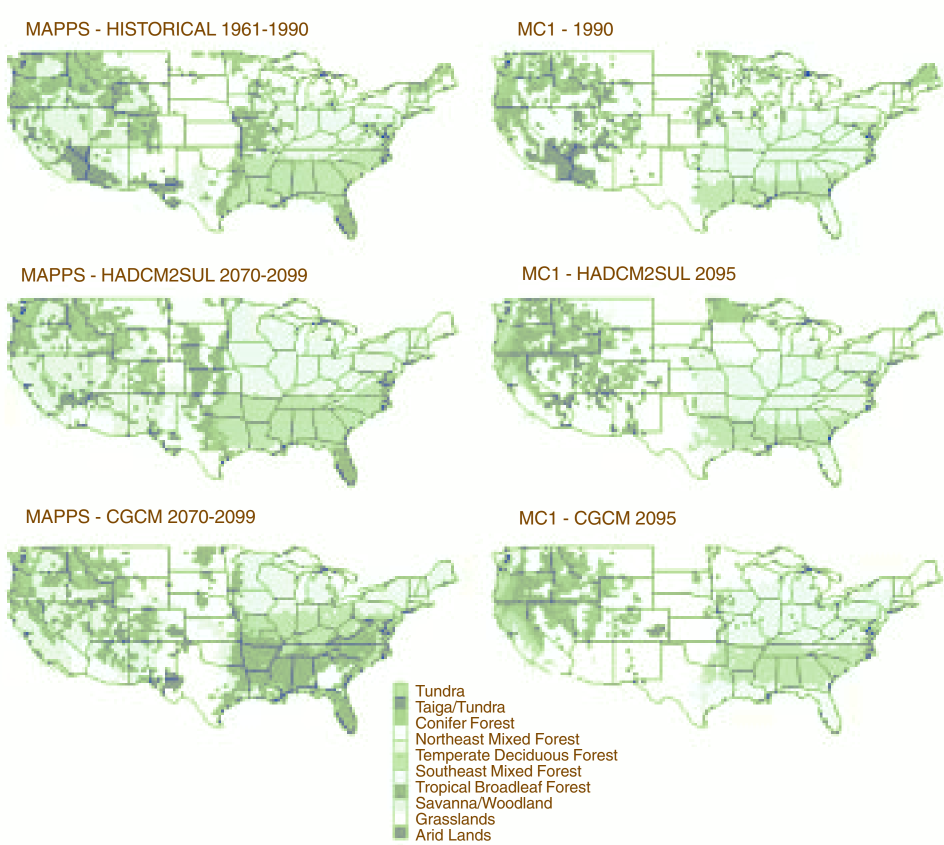

Figure 18.8—Current and future vegetation distribution as predicted by the biogeography models MC1 and MAPSS (Bachelet and others, in press).

could mean greater carbon storage potential and increased drought tolerance. For some species, however, acclimation to increased CO_2 levels has included a reduction in photosynthesis (Intergovernmental Panel on Climate Change 1998). Such down regulation may occur when nutrient availability does not increase with CO_2 (National Assessment Synthesis Team 2001). Recent studies point out that acclimation to CO_2 may not be as widespread when roots are unconstrained and that leaf conductance may not be reduced. In this case, forests might produce more leaf area under elevated CO_2, but, because transpiration could also increase under increased temperatures, soil drying and drought effects could result (Intergovernmental Panel on Climate Change 1998).

If precipitation patterns decrease across the region, rates of evaporation and transpiration could increase without offset, resulting in declines in runoff and consequent drops in river flows, groundwater levels, and recharge. Alternatively, if substantial increases in precipitation occur, increases in runoff and river flows could be expected (Intergovernmental Panel on Climate Change 1998).

Wetlands may be particularly affected by variability in the amount and seasonality of rainfall. As a result, flood protection, water filtering, carbon storage, and other wetland functions may be significantly altered (Intergovernmental Panel on Climate Change 1998).

Results from the biogeography models suggest a northward shift in forest productivity over the next century, but they do not consider changes in management that could potentially ameliorate adverse effects. In summary, forest productivity in the South will likely increase over the next century as a result of atmospheric CO_2 enrichment, provided that: (1) precipitation and temperature changes do not offset the enrichment benefits by inducing water stress, and (2) abiotic stressors such as O_3 do not reduce growth rates significantly. Strategies to increase WUE or water availability could be used to prepare for a potentially warmer and drier climate.

Interactions between climate, extreme weather-related events, and forest health—Disturbance effects often cascade. Drought may weaken tree vigor, leading to insect and disease infestations or fire. Disease and insect infestations promote future fires by increasing fuel loads. Fires then promote future infestations by compromising tree defenses.

Changes in forest management, land use, and atmospheric chemistry interact with natural disturbances. For example, in the Southern Appalachian Mountains, climate change, increased O_3 exposure, continued acid deposition, and infestations of non-native insects may increase stress and mortality in red spruce and Fraser fir forests. In some combinations, negative impacts from disturbances may be ameliorated: under drought conditions, leaf stomata tend to close, reducing the effects of elevated O_3 exposure on seedlings (McLaughlin and Percy 1999).

Interactions between extreme weather events are common in the South, and the impacts of multiple extreme events are greater than the sum of the individual events (Paine and others 1998). For example, although hurricanes rapidly lose strength after reaching land, sustained winds of over 40 miles per hour may occur hundreds of miles inland. Soil saturation, which occurs when large amounts of rain accompany the winds, can reduce tree-root support. Under these conditions, even a moderate wind can blow down a mature tree. Without these multiple stresses, little or no forest damage would have occurred.

Interactions between extreme weather events are further complicated by the effects of other forest ecosystem stressors. Drought often weakens tree vigor, increasing the potential for insect or disease attacks. If tree mortality results from these combined stresses, fuel loads and the likelihood of future wildfires can also increase. An example of interactions of this type can be observed in the Southern Appalachian Mountains, where increased O_3 exposure and periodic drought have increased the infestation rate of native and non-native insects in red spruce and Fraser fir forests. The combined stressor effects are partially responsible for increased mortality in these high-elevation tree species. Climate change may cause these integrated events and their compounded influences to occur slowly, unpredictably, and in unique configurations.

Understanding the effects of climate change on extreme weather events is critical for managing broad-scale disturbances before, during, and after they occur. Forest management could play a key role in minimizing negative forest responses, thus sustaining forests through long-term climate change and short-term intense weather events.

Needs for Additional Research on Climate Change and Extreme Weather-Related Events

To project climate change and variability at a regional scale, increased spatial resolution in long-term climate change scenarios is needed. Precipitation predictions for the South are particularly problematic; different climate scenarios simulate large differences in precipitation pattern changes over the next century. A recent report on climate change in the gulf coast region of the South points out that the CGCM1 climate change scenario differs from the HadCM2Sul in its projections of changes in runoff (increase), soil moisture (decrease), and subregional precipitation patterns (significant overall decrease) (Twilley and others 2001). Both scenarios, however, agree that more intense rainfall will occur across the region. The uncertainty resulting from different climate change projections means that regional assessment developers and users should consider a wide range of potential futures.

There is a limited understanding of climate change impacts on extreme weather events. Multiple stressors and their regional-scale integrated effects are critical areas for future research. As these phenomena are measured and understood, broad-scale forest ecosystem monitoring programs should be implemented to provide continuous, current information on forest conditions and to allow for the validation of modeling results.

In field chamber experiments, coexposure to increased CO_2 and O_3 has been shown to offset predicted gains in forest growth from elevated CO_2 and to increase damage from O_3. More research is needed to consider the combined effect of these gases (McLaughlin and Percy 1999).

Carbon Sequestration

Carbon Sequestration Methodology: Current Conditions

Forest carbon is generally reported in terms of carbon in above- and belowground tree components, understory vegetation, forest floor litter, and soil with more than 90 percent stored in the tree and soil components (Plantinga and others 1999). The carbon cycle involves carbon fluxes between the atmosphere, oceans, and terrestrial biosphere, with active reserves transferred through biological, physical, and chemical mechanisms (Sarmiento and Wofsy 1999). Processes that naturally increase the emission of CO_2 have historically been balanced by processes that accelerate carbon sequestration, thus resulting in little change to atmospheric CO_2 levels (U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). The current large increase in atmospheric CO_2, however, implies that CO_2 emissions exceed carbon sequestration (U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999).

Forest structure and land use—Forests contain approximately 85 percent of global aboveground carbon (Huntington 1995); however, the relationship between carbon sequestration and forest structural characteristics is complex. On average, regenerating southern forests initially act as net carbon sources but generally become carbon sinks within 10 to 15 years due to rapid carbon accumulation (fig. 18.9). Carbon accumulation continues to increase until stands reach maturity. After this time, net carbon uptake begins to decrease and may approach zero (Plantinga and others 1999). Site differences (including climate, topography, and soil) greatly influence the forest productivity and carbon sequestration potential of an area. These differences are further enhanced when considering previous land use practices and their effect on soil fertility. Land use change, not climate change or atmospheric chemistry, has been, and probably will continue to be, the most important determinant of carbon storage, uptake, and release in terrestrial ecosystems (Sampson and others 1993).

Forest soils and long-term carbon sequestration—Forest soils appear to be the best available long-term option for storing carbon in terrestrial ecosystems because the residence time of carbon in soils is much longer than in aboveground biomass (U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). Approximately 50 to 60 percent of the carbon in temperate forest ecosystems is found in the soil organic matter (SOM) (Huntington 1995; U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). Soils with high concentrations of carbon in SOM have improved nutrient absorption, retention, and resistance to erosion (U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999), factors especially important for forest productivity and carbon sequestration (Johnson 1992; U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). However, understanding and quantifying soil carbon pools have been complicated by a lack of available data (Huntington 1995, Sanchez 1998). For example, temperature is an important controller of soil organic carbon dynamics, but the effects of different temperature scenarios on soil carbon are not fully understood (Garten and others 1999).

Land management practices and land use changes can directly affect the ability of soils to sequester carbon. Practices that protect soil and reduce erosion greatly improve the potential of those soils to sequester carbon (U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). Comparing disturbed (previously harvested) and relatively undisturbed (no known cultivation or harvesting since European settlement) watersheds in Georgia, Huntington (1995) found that disturbed sites have potential for large increases in soil carbon storage. Harvesting followed by cultivation also results in substantial losses of SOM; intensive cultivation after forest harvesting can cause SOM to decrease by 50 percent in the upper 7.87 inches of soil (Huntington 1995; U.S. Department of Energy, Office of Science, Office of Fossil Energy 1999). This practice can also result in overall soil carbon losses of 30 to 60 percent (Huntington 1995). Converting cultivated land to forests, on the other hand, provides an important carbon sink. There are clearly opportunities to increase carbon storage in soil through reforestation of former agricultural land and adoption of forest management practices like fertilization and genotype improvement that increase net rates of biomass production (Johnson 1992). Timber harvesting followed by forest regrowth does not necessarily reduce soil carbon storage (Huntington 1995) but may increase soil carbon storage (Johnson 2001). When followed by erosion and subsequent loss of SOM, however, harvesting does result in substantial losses of soil carbon and fertility. Harvesting practices may increase soil carbon when specifically designed to do so by burying forest floor material and downed dead wood in the soil. On a broad scale, because soil fertility losses may be partially mitigated by increases in CO_2 and nitrogen deposition, air and water pollution may lead to soil degradation and further carbon loss (Huntington 1995, Sarmiento and Wofsy 1999).

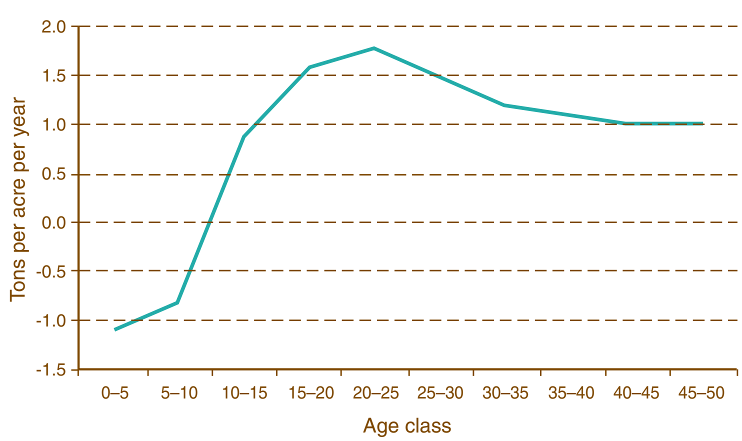

Figure 18.9—Average carbon uptake on land by age class of regeneration after harvest (Birdsey 1992).

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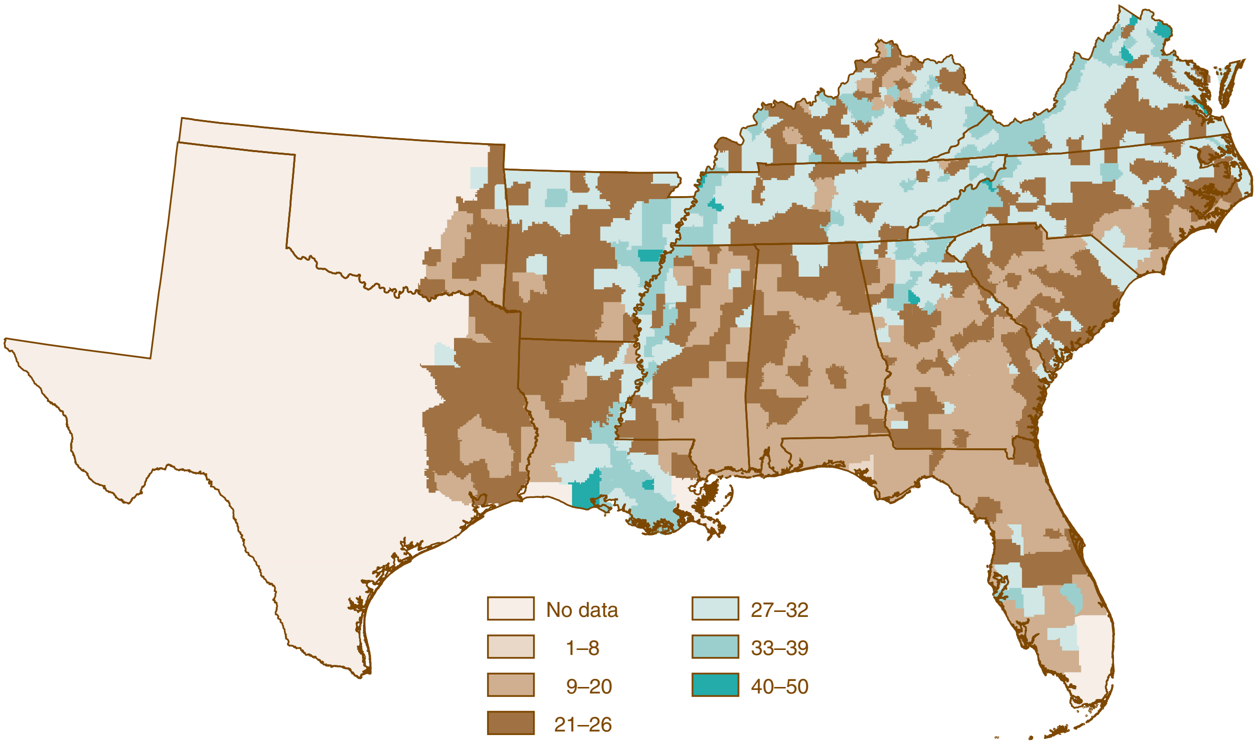

Figure 18.10—Total aboveground carbon per acre in southern forests (Personal Communication. 2000. L.S. Heath, Project Leader, and J.E. Smith, Plant Physiologist, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073) [estimates based on 1997 USDA Forest Service Forest Inventory and Analysis data and FORCARB results (inventory begins in 1990, older products are not counted, and future predictions are cumulative amounts)].

Long-term carbon storage in harvested wood—Harvested wood provides options for long-term carbon storage, and, when burned, a substitute for nonrenewable fossil fuel-derived emissions (Heath and others 1996, Skog and Nicholson 1998). Carbon can be stored for centuries in furniture or housing. When discarded in anaerobic landfills like those currently used in the United States, wood stores carbon for long periods.

Carbon Sequestration Methodology: Future Predictions

Given the large quantities of SOM lost through erosion and cultivation, it is not known if soil carbon will be able to return to predisturbance levels (Huntington 1995). Indications for the forested Piedmont, including reforested abandoned agricultural lands, are that the rate of sequestration will begin to slow later this century as soil carbon approaches predisturbance levels, thus reducing the potential of these soils to sequester additional carbon (Huntington 1995). Whether forests are managed for maximum sustained yield of biomass or maximum financial return, they will rarely contain more than approximately one-third of the carbon stored in a forest grown to maximum biomass (Cooper 1982).

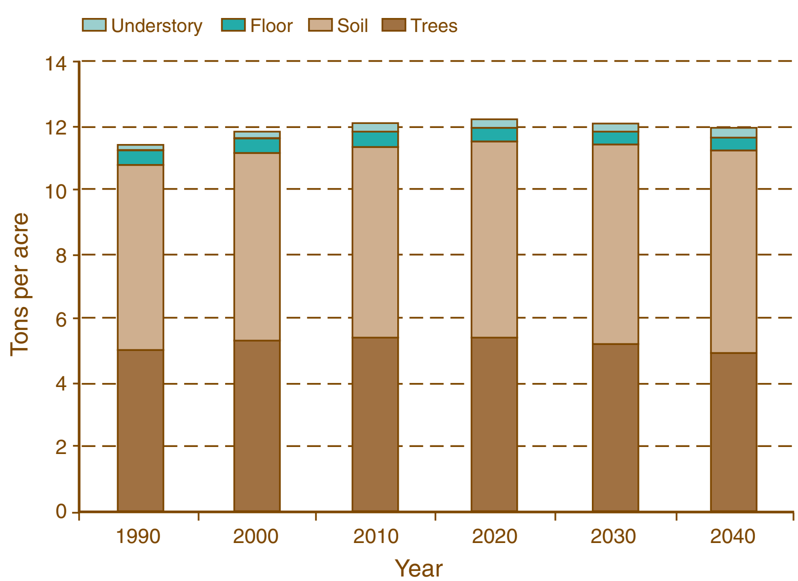

Figure 18.11—Current and future carbon inventory in southern forests by (Personal Communication. 2000. L.S. Heath, Project Leader, and J.E. Smith, Plant Physiologist, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073) [estimates based on 1997 USDA Forest Service Forest Inventory and Analysis data and FORCARB results (note that carbon in products is not included)].

Carbon Sequestration Data Sources

The current and potential carbon storage and flux of actual vegetation have been examined in the United States using data from the USDA Forest Service, Forest Inventory and Analysis databases (Miles and others 2001) and models such as FORCARB (Heath and Birsey 1993, Plantinga and Birdsey 1993). FORCARB provides historical estimates and projections of carbon in forest ecosystems and harvested wood; an explanation of the uncertainty associated with FORCARB projections can be found in Heath and Smith (2000). Baseline carbon sequestration projections are predicated on preliminary results from the updated work of Haynes and others (1995).

Carbon Sequestration Results

Average aboveground carbon in southern forests is approximately 25 tons per acre (fig. 18.10). Higher averages are found in the Appalachian Mountains and the Mississippi Alluvial Valley. Over the last 40 years, increases in biomass and organic matter on U.S. forest lands have added only enough stored carbon to offset 25 percent of national emissions for the same period (Birdsey and Heath 1997). This result has important implications because the overall carbon inventory in southern forests is predicted to remain relatively stable through 2040 (fig. 18.11).

Nonindustrial private forests store more total aboveground carbon than all public and industrial lands combined due to a much higher percentage of forest land being privately owned (table 18.3). Approximately 42 percent of the aboveground carbon in southern forests is in the oak-hickory forest-type group (table 18.4), which dominates nonindustrial land (table 18.5). Whereas the percentage of the oak-hickory forest-type group is expected to decrease slightly by 2020, it will continue to dominate nonindustrial private forests (see chapter 14 for more information). Volume and stocking density measurements on these tracts indicate that they are typically understocked and managed

Table 18.3—Aboveground tree carbon in southern forests by owner group[a]

Owner group	Aboveground carbon	
	Million tons	*Tons/acre*
National forest	343	29
Other public	283	27
Forest industry	708	19
Other private	3,369	24

[a] Personal Communication. 2000. L.S. Heath, Project Leader, and J.E. Smith, Plant Physiologist, USDA Forest Service, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073.

Table 18.4—Aboveground tree carbon in southern forests by forest-type group[a]

Forest-type group	Aboveground carbon	
	Million tons	*Tons/acre*
Longleaf-shortleaf pine	179	14
Loblolly-shortleaf pine	932	19
Oak-pine	619	21
Oak-hickory	1,964	26
Oak-gum-cypress	911	32
Elm-ash-cottonwood	61	27
Maple-beech-birch	37	32

[a] Personal Communication. 2000. L.S. Heath, Project Leader, and J.E. Smith, Plant Physiologist, USDA Forest Service, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073.

Table 18.5—Current and predicted southern forest land distribution by ownership and forest type[a]

Forest type	Forest industry		Timber investment management organizations		Nonindustrial private forest land	
	2000	2020	2000	2020	2000	2020
	Percent					
Planted pine	63	81	69	81	10	14
Natural pine	11	2	9	3	14	10
Oak pine	4	2	2	1	14	13
Upland hardwoods	6	1	3	1	40	35
Bottomland hardwoods	12	11	9	8	14	12
Not stocked	1	1	3	1	1	1
Reserved	3	2	5	5	7	15

[a] Personal Communication. 2000. J. Siry, North Carolina State University, Department of Forestry, Raleigh, NC.

with low intensity (National Research Council Board on Agriculture 1998). Private landowners could make a significant contribution to carbon sequestration efforts by increasing stocking levels.

Southern pines dominate southern industrial forests due to their fast growth and high product value and therefore make up more than 60 percent of all forest industry and Timber Investment Management Organization forest land (see chapter 14 for more information). This proportion is predicted to increase by 10 to 20 percent by 2020 (table 18.5). Because intensive management strategies have been shown to increase planted pine yields 70 percent more than traditional management (see chapter 14 for more information), manipulating commercial sites will be an important carbon sequestration tool.

In the South, harvesting forests initially results in a net carbon loss, but sites begin to show a net carbon gain 10 to 15 years after harvest. Most of the carbon in harvested wood is either lost through emissions, stored in finished products, or burned for energy as a substitute for fossil fuels. Residual wood left on site decays and returns to the soil or goes off to the atmosphere as CO_2. Waste and discarded products are buried in landfills where the carbon continues to be stored. Figure 18.12 shows an example of the estimated disposition of carbon on a highly productive southeastern pine site after 80 years with a rotation age of 40 years. Whereas 53 percent of the carbon sequestered in trees is lost in emissions and energy (wood burned as a substitute for fossil fuels), 39 percent of the carbon remains stored in products and landfills. Because the total amount of carbon in wood removed from southern forests is expected to increase between now and 2035 (fig. 18.13), high levels of emissions could continue to counteract carbon sequestration efforts. However, the emissions should be estimated carefully because burning wood for energy mitigates fossil fuel emissions.

Carbon Sequestration Discussion and Conclusions

Despite many volumes of research detailing individual tree responses to elevated CO_2 and tree stresses, the complexity of ecosystem interactions

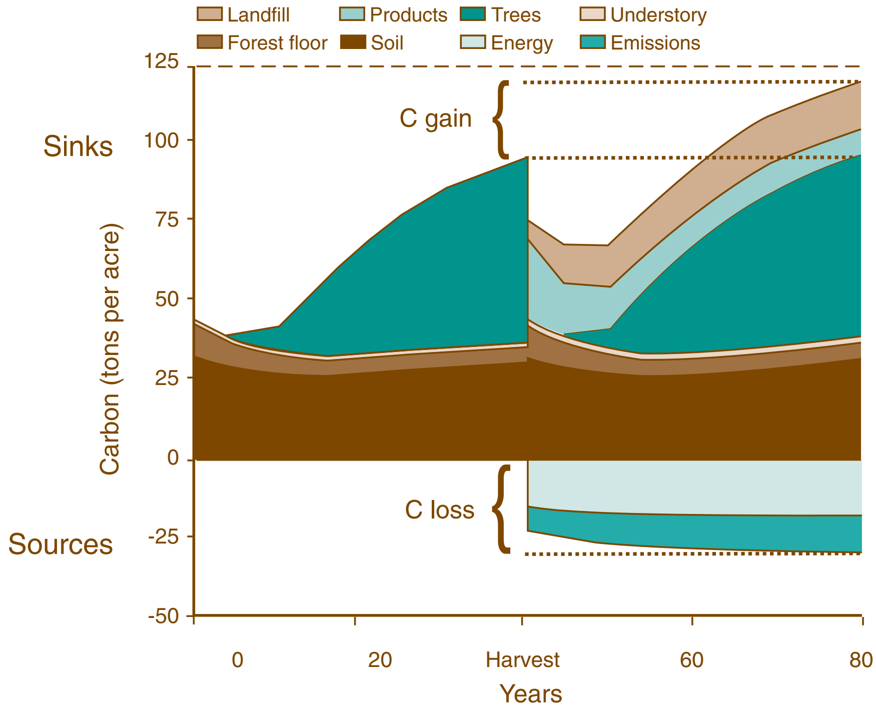

Figure 18.12—Estimated disposition of carbon on a highly productive southern site 40 years after harvest (Heath and Birdsey 2000). The energy category represents wood burned for energy capture, and the emissions category represents wood burned without energy capture.

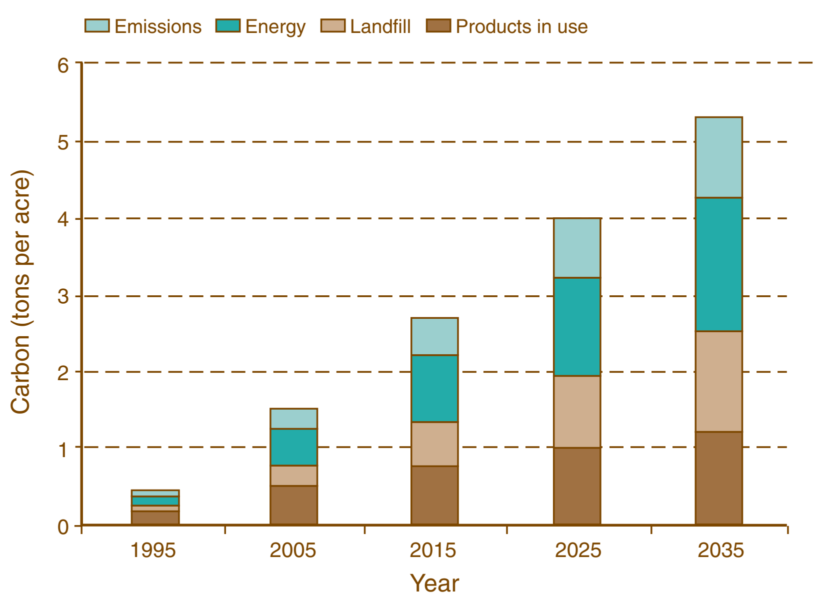

Figure 18.13—Fate of current and future carbon in wood removed from southern forests (Personal Communication. 2000. L.S. Heath, Project Leader, and J.E. Smith, Plant Physiologist, Northeastern Research Station, 11 Campus Blvd., Newtown Square, PA 19073) [estimates based on 1997 USDA Forest Service Forest Inventory and Analysis data and FORCARB results (inventory begins in 1990, older products are not counted, and future predictions are cumulative amounts) (emissions category represents wood burned without energy capture) (energy category represents wood burned for energy capture)].

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has made it difficult to understand and predict whole system responses. Currently, there is very little understanding of the relationship between carbon sequestration and species composition and interactions among CO_2, O_3, nitrogen, temperature, and precipitation (Aber and others 2001). The long-term impacts on manipulated sites are not completely understood. Consideration of site characteristics and past land use should be an important component of forest sustainability and carbon sequestration research. Maximizing carbon per acre on all land will be an important step toward increasing long-term carbon storage.

The lack of understanding of interactions in forest processes results in uncertainty when estimating current and future carbon budgets. Uncertainty is defined by Smith and Heath (2000) as the inability to precisely quantify an unknown, but unique, inventory of carbon in a given forest management unit for a particular year. Uncertainty can be minimized through multisite, multifactorial experiments; but the costs, time constraints, and logistics involved limit the feasibility of such an approach (Aber and others 2001). It will be important to understand both the trends and uncertainties in carbon pool estimates when making policy decisions (Aber and others 2001). Until we have a greater understanding of carbon flows and the potential interactions involved, research should be aimed toward identifying areas that will contribute most to reducing overall uncertainty (Heath and Smith 2000).

Increases in anthropogenic CO_2 emissions and the possible resulting global warming have created the need for increased carbon sequestration in forests and harvested wood. Current southern forest carbon inventory is approximately 5.5 billion tons in trees alone (Birdsey and Heath 1995). Although additional research is requiqet to further understand carbon fluxes, it is clear that southern forests offer an enormous opportunity for capturing CO_2 and storing it as carbon while still providing wood products and other benefits. Future policies involving incentive programs and forest management intensity are factors that will potentially affect carbon sequestration rates. It should be acknowledged, however, that land use change, more so than changes in climate or atmospheric chemistry, has been, and will likely continue to be, the most significant determinant of terrestrial carbon storage, uptake, and release.

Carbon Sequestration Needs for Additional Research

Future research and measurement must focus on long-term storage of carbon in forests, specifically in soils, forest floor material, aboveground biomass, and harvested wood. The potential for substituting wood fuel for fossil fuel needs additional review. Information about methods to assess site differences, the influence of previous land use practices, management methods that could be adopted to increase carbon storage, and responses to potential climate change scenarios will also be crucial to understanding the ability of forests to sequester carbon.

Conclusions

This Assessment highlights the integrated nature of abiotic factors that cumulatively affect overall forest health. Acid deposition does not pose a significant threat to southern forest vegetation except in the Southern Appalachian Mountain high-elevation spruce-fir forests. Nitrogen-limited forests may respond to continued nitrogen deposition with increased growth rates. Acid deposition is not causing significant damage to stream chemistry in the South. However, areas in the Southern Appalachian Mountains are showing signs of acidification.

Southern pine forest growth rates are being impacted by ambient ozone levels. For seedlings, the annual growth reductions are between 2 and 5 percent. For mature pines, the annual growth reductions are between 0 and 10 percent. Ozone effects on mature southern yellow pines have resulted in decreased growth rates. Projected increases in ozone concentrations will likely have significant negative impacts on pine forests in the South.

Forest area and growth rates could increase across the South with moderate increases in air temperatures and carbon dioxide concentrations during the 21st century. Severe temperature increases could negatively affect forest productivity and area, especially if precipitation rates do not increase to compensate for increased water demands. Carbon storage in southern forest ecosystems, including public, private, and industrial forests, could make a significant sequestration contribution. Future policies, incentive programs, and forest management intensity will affect carbon sequestration rates. However, land use change, more than changes in climate or atmospheric chemistry, has been, and probably will continue to be, the most important determinant of carbon storage, uptake, and release in terrestrial ecosystems. Detailed spatial and temporal predictions of abiotic stressor effects on forest sustainability are not possible without long-term improvements in regional monitoring and studies designed to understand specific and integrated broad-scale stress responses at forest ecosystem, community, and species levels.

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Literature Cited

Aber, J.; Neilson, R.; McNulty, S. [and others]. 2001. Forest processes and global environmental change: predicting the effects of individual and multiple stressors. BioScience. 51(9): 735–751.

Allen, E.R.; Gholz, H.L. 1996. Air quality and atmospheric deposition in Southern U.S. forests. In: Fox, S.; Mickler, R.A., eds. Impact of air pollutants on southern pine forests. Ecological Studies 118. New York: Springer-Verlag: 83–170. Chapter 3.

Aneja, V.P.; Li, Z. 1990. Characterization of ozone at high elevations in the Eastern United States. 90–95.9. Proceedings, 83rd annual meeting. [Pittsburgh, PA]: [Air and Waste Management Association]. [Number of pages unknown].

Aneja, V.P.; Li, Z.; Das, M. 1994. Ozone case studies at high elevation in the Eastern United States. Chemosphere. 29(8): 1711–1733.

Bachelet, D.; Neilson, R.P.; Lenihan, J.M.; Drapek, R.J. 2001. Climate change effects on vegetation distribution and carbon budget in the United States. Ecosystems. 4(3): 164–185.

Bachelet, Dominique; Neilson, Ronald P. 2000. Biome redistribution under climate change. In: Joyce, Linda A.; Birdsey, Richard, eds. The impact of climate change on America's forests: a technical document supporting the 2000 USDA Forest Service RPA assessment. Gen. Tech. Rep. RMRS–GTR–59. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 18–44. Chapter 2.

Berrang, P.; Meadows, J.S.; Hodges, J.D. 1996. An overview of responses of southern pines to airborne chemical stresses. In: Fox, S.; Mickler, R.A., eds. Impact of air pollutants on southern pine forests. Ecological Studies 118. New York: Springer-Verlag: 196–243. Chapter 5.

Berz, G.A. 1993. Global warming and the insurance industry. Interdisciplinary Science Reviews. 18: 120–125.

Birdsey, R.A. 1992. Carbon storage and accumulation in United States forest ecosystems. Gen. Tech. Rep. WO–59. Washington, DC: U.S. Department of Agriculture, Forest Service. 51 p.

Birdsey, R.A.; Heath, L.S. 1995. Carbon changes in U.S. forests. In: Joyce, L.A., ed. Productivity of America's forests and climate change. Gen. Tech. Rep. RM–271. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 70 p.

Birdsey, R.A.; Heath, L.S. 1997. The forest carbon budget of the United States. In: USDA Forest Service global change research program highlights: 1991–1995. Gen. Tech. Rep. NE–237. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 81–85.

Blancher, P.J. 1991. Acidification: implications for wildlife. Transactions of the North American wildlife natural resource conference. Washington, DC: Wildlife Management Institute. 56: 195–204.

Bohm, M. 1992. Air quality and deposition. In: Olson, R.K.; Binkley, D.; Bohm, M., eds. Air pollution in western forests. Ecological Studies 97. New York: Springer-Verlag: 63–152.

Bondietti, E.A.; Mclaughlin, S.B. 1992. Evidence of historical influences of acidic deposition on wood and soil chemistry. In: Johnson, D.W.; Linderg, S.E., eds. Atmospheric deposition and forest nutrient cycling. New York: Springer-Verlag: 358–377.

Bratkovich, S.; Burban, L.; Katovich, S. [and others]. 1993. Flooding and its effects on trees. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. http://www.na.fs.fed.us/spfo/pubs/n_resource/flood/cover.htm. [Date accessed: July 20, 2001].

Bulger, A.; Cosby, J.; Webb, R. 1998. Acid rain: current and projected status of coldwater fish communities in the Southeastern U.S. in the context of continued acid deposition. Arlington, VA: Trout Unlimited: 1-34.

Burke, M.K.; Lockaby, B.G.; Conner, W.H. 1999. Aboveground production and nutrient circulation along a flooding gradient in a South Carolina Coastal Plain forest. Canadian Journal of Forest Research. 29: 1402–1418.

Chameides, W.L.; Kasibhatla, P.S.; Yeinger, J.; Levy, H. 1994. Growth of continental-scale metro-agro-plexes, regional ozone pollution, and World food production. Science. 264(5155): 74–77.

Chameides, W.L.; Lodge, J.P. 1992. Tropospheric ozone: formation and fate. In: Lefohn, A.S., ed. Surface level ozone exposures and their effects on vegetation. Chelaea, MI: Lewis Publishing: 5–30.

Chappelka, A.H.; Freer-Smith, P.H. 1995. Predisposition of trees by air pollutants to low temperature and moisture stress. Environmental Pollution. 87(1): 105–117.

Chappelka, A.H.; Samuelson, L.J. 1998. Ambient ozone effects on forest trees of the Eastern United States: a review. New Phytologist. 139(1): 91–108.

Cobb, F.W.; Wood, D.L.; Stark, R.W.; Parmeter, J.R. 1968. Theory on relationships between oxidant injury and bark beetle infestation. Hilgardia. 39(6): 141.

Cooper, C.F. 1982. Carbon storage in managed forests. Canadian Journal of Forest Research. 13: 155–166.

Dale, Virginia H.; Joyce, Linda A.; McNulty, Steve [and others]. [In press]. Forest disturbances and climate change. BioScience.

Dale, Virginia H.; Joyce, Linda A.; McNulty, Steve [and others]. 2001. Climate change and forest disturbances. BioScience. 51(9): 723–734.

Dougherty, P.M.; Teskey, R.O.; Jarvis, P.G. 1992. Development of MAESTRO, a process-based model for assessing the impact of ozone on net carbon exchange of loblolly pine trees. In: Flagler, R.B., ed. The response of southern commercial forests to air pollution: transactions. TR–21. Pittsburgh, PA: Air and Waste Management Association: 37–48.

Drohan, J.R.; Sharpe, W.E. 1997. Long-term changes in forest soil acidity in Pennsylvania. Water, Air, and Soil Pollution. 95: 299–311.

Duever, M.J.; McCollom, J.M. 1993. Hurricane Hugo effects on old-growth floodplain forest communities at Four Holes Swamp, South Carolina. Gen. Tech. Rep. SO–93. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 665 p.

Dull, C.W.; Ward, J.E.; Brown, H.D. [and others]. 1988. Evaluation of spruce and fir mortality in the Southern Appalachian Mountains. Prot. Rep. R&PR 13. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 92 p.

Emanuel, K.A. 1987. The dependence of hurricane frequency on climate. Nature. 326: 483–485.

Eyre, F.H. 1980. Southern forest region. In: Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters: 51–77.

Fenn, M.E.; Poth, M.A.; Aber, J.D. [and others]. 1998. Nitrogen excess in North American ecosystems: predisposing factors, ecosystem responses, and management strategies. Ecological Applications. 8(3): 706–733.

Fishman, J. 1991. The global consequences of increasing tropospheric ozone concentrations. Chemosphere. 22: 685–695.

Flagler, R.B; Chappelka, A.H. 1996. Growth response of southern pines to acidic precipitation and ozone. In: Fox, S.; Mickler, R.A., eds. Impact of air pollutants on southern pine forests. Ecological Studies 118. New York: Springer-Verlag: 388–424.

Flannigan, M.D.; Stocks, B.J.; Wotton, B.M. 2000. Climate change and forest fires. The Science of the Total Environment. 262: 221–229.

Garten, C.T., Jr.; Post, W.M., III; Hanson, P.J.; Cooper, L.W. 1999. Forest soil carbon inventories and dynamics along an elevation gradient in the Southern Appalachian Mountains. Biogeochemistry. 45: 115–145.

Gornitz, V. 2001. Sea level rise. NASA Goddard Institute for Space Studies Research. http://www.giss.nasa.gov/research/intro/gornitz_01/. [Date accessed: February 01].

Hanson, Paul J.; Weltzin, Jake F. 2000. Drought disturbance from climate change: response of United States forests. The Science of the Total Environment. 262: 205–220.

Haynes, R.W.; Adams, D.M.; Mills, J.R. 1995. The 1993 RPA timber assessment update. Gen. Tech. Rep. RM–259. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 23 p.

Heath, L.S.; Birdsey, R.A. 1993. Carbon trends of productive temperate forests of the coterminous United States. Water, Air, and Soil Pollution. 70: 279–293.

Heath, L.S.; Birdsey, R.A. 2000. USDA global change program office news. Forest inventory methods and carbon analysis. http://www.usda.gov/oce/gcpo/gcponews.htm. [Date accessed: December 29].

Heath, L.S.; Birdsey, R.A.; Row, C.; Plantinga, A.J. 1996. Carbon pools and flux in U.S. forest products. In: Apps, M.J.; Price, D.T., eds. NATO ASI Series I: 40. Berlin: Springer-Verlag: 271–278.

Heath, L.S.; Smith, J.E. 2000. An assessment of uncertainty in forest carbon budget projections. Environmental Science and Policy. 3: 73–82.

Hebert, P.J.; Jarrell, J.D.; Mayfield, M. 1997. The deadliest, costliest, and most intense United States hurricanes of this century (and other frequently requested hurricane facts). Tech. Memor. NWS TPC–1. Miami: National Weather Service. [Number of pages unknown].

Heck, W.W.; Furiness, C.S.; Cowling, E.B.; Sims, C.K. 1998. Effects of ozone on crop, forest, and natural ecosystems: assessment of research needs. Environmental Manager. October: 11–22.

Herlihy, A.T.; Kaufmann, P.R.; Stoddard J.L. [and others]. 1996. Effects of acidic deposition on aquatic resources in the Southern Appalachians with a special focus on class I wilderness areas. Asheville, NC: Southern Appalachian Mountains Initiative. [Number of pages unknown].

Hileman, B. 1997. Global climate change: nations, business interests struggle over policies before Kyoto meeting. Chemical & Engineering News. 75(46): 8–16. http://pubs.acs.org/hotartcl/cenear/971117/global.html. [Date accessed: July 20, 2001].

Hogsett, W.E.; Weber, J.E.; Tingey, D. [and others]. 1997. An approach for characterizing tropospheric ozone risk to forests. Environmental Management. 21(1): 105–120.

Huntington, T.G. 1995. Carbon sequestration in an aggrading forest ecosystem in the Southeastern U.S.A. Soil Science Society of America Journal. 59: 1459–1467.

Iles, J.K. 1993. Effects of flooding on trees. In: Horticulture and Home Pest News. http://www.ipm.iastate.edu/ipm/hortnews/1993/7-14-1993/flood.html. [Date accessed: July 20, 2001].

Intergovernmental Panel on Climate Change. 1998. The regional impacts of climate change— an assessment of vulnerability: a special report by the Intergovernmental Panel on Climate Change. United Kingdom: Cambridge University Press. 514 p.

Irland, Lloyd. 2000. Ice storms and forest impacts. The Science of the Total Environment. 262: 231–242.

Jagger, P.; White, W.; Sedjo, R. 1999. El Niño, ice storms, and the market for residential fuelwood in Eastern Canada and the Northeastern U.S. Discn. Pap. 99–44. Washington, DC: Resources for the Future. 14 p. http://www.rff.org/disc_papers/PDF_files/9944.pdf. [Date accessed: July 21, 2001].

Johnson, D.W. 1992. Effects of forest management on soil carbon storage. Water, Air, and Soil Pollution. 64: 83–120.

Johnson, D.W.; Binkley, D.; Conklin, P. 1995. Simulated effects of atmospheric deposition harvesting, and species change on nutrient cycling in a loblolly pine forest. Forest Ecology and Management. 76: 29–45.

Johnson, D.W.; Curtis, P.S. 2001. Effects of forest management on soil carbon and nitrogen storage: a meta-analysis. Forest Ecology and Management. 140: 227–238.

Johnson, D.W.; Van Miegroet, H.; Lindberg, S.E. [and others]. 1991. Nutrient cycling in red spruce forests of the Great Smoky Mountains. Canadian Journal of Forest Research. 21: 769–787.

Karl, T.R.; Knight, R.W.; Easterling, D.R.; Quayle, R.G. 1995a. Indices of climate change for the United States. Bulletin of the American Meteorological Society. 77: 279–292.

Karl, T.R.; Knight, R.W.; Plummer, N. 1995b. Trends in high-frequency climate variability in the 20th century. Nature. 377: 217–220.

Karl, T.R.; Knight, R.W.; Easterling, D.R.; Quayle, R.G. 1995c. Trends in U.S. climate during the 20th century. Consequences. Vol. 1. http://www.gcrio.org/CONSEQUENCES/spring95/Climate.html. [Date accessed: July 20, 2001].

Kelly, J.M.; Samuelson, L.J.; Edwards, G.S. [and others]. 1995. Are seedlings reasonable surrogates for trees? An analysis of ozone impacts on *Quercus rubra*. Water, Air, and Soil Pollution. 85: 1317–1324.

Kress, L.W.; Allen, H.L.; Mudano, J.E.; Stow, T.K. 1992. Impact of ozone on loblolly pine seedling foliage production and retention. Environmental Toxicology and Chemistry. 11(8): 1115–1128.

LeBlanc, D.C.; Nicholas, N.S.; Zedaker, S.M. 1992. Prevalence of individual tree growth decline in red spruce populations of the Southern Appalachian Mountains. Canadian Journal of Forest Research. 22(6): 905–914.

Lugo, A.E.; Scatena, F.N. 1995. Ecosystem-level properties of the Luquillo Experimental Forest, with emphasis on the tabonuco forest. In: Lugo, A.E.; Lowe, C., eds. Tropical forests: management and ecology. New York: Springer Verlag: 59–108.

Lugo, A.E.; Scatena, F.N. 1996. Background and catastrophic tree mortality in tropical moist, wet, rain forests. Biotropica. 28: 585–599.

Lugo, Ariel E. 2000. Effects and outcomes of Caribbean hurricanes in a climate change scenario. The Science of the Total Environment. 262: 243–251.

Maier-Maercker, U. 1999. Predisposition of trees to drought stress by ozone. Tree Physiology. 19(2): 71–78.

Malmer, N. 1976. Acid precipitation: chemical changes in the soil. Ambio. 5: 231–234.

Manion, P.D. 1981. Tree disease concepts. Englewood Cliffs, NJ: Prentice-Hall. [Number of pages unknown].

McLaughlin, S.; Percy, K. 1999. Forest health in North America: some perspectives on actual and potential roles of climate and air pollution. Water, Air, and Soil Pollution. 116: 151–197.

McLaughlin, S.B.; Downing, D.J. 1995. Interactive effects of ambient ozone and climate measured on growth of mature forest trees. Nature. 374: 252–254.

McLaughlin, S.B.; Downing, D.J. 1996. Interactive effects of ambient ozone and climate measured on growth of mature loblolly pine trees. Canadian Journal of Forest Research. 26(4): 670–681.

McLaughlin, S.B.; Joslin, J.D.; Robarge, W. [and others]. 1998. The impacts of acidic deposition and global change on high elevation Southern Appalachian spruce-fir forests. In: Mickler, R.A.; Fox, S., eds. The productivity and sustainability of southern forest ecosystems in a changing environment. New York: Springer-Verlag: 254–277.

McLaughlin, S.B.; Kohut, R. 1992. The effects of atmospheric deposition and ozone on carbon allocation and associated physiological processes in red spruce. In: Eagar, C.; Adams, B., eds. Ecology and decline of red spruce in the Eastern United States. New York: Springer-Verlag: 338–382.

McNulty, S.G.; Aber, J.D. 1993. Effects of chronic nitrogen additions on nitrogen cycling in a high-elevation spruce-fir stand. Canadian Journal of Forest Research. 23: 1252–1263.

McNulty, S.G.; Aber, J.D.; Newman, S.D. 1996. Nitrogen saturation in a high elevation New England spruce-fir stand. Forest Ecology and Management. 84: 109–121.

McNulty, S.G.; Moore, J.A.; Iverson, L. [and others]. 2000. Application of linked regional scale growth, biogeography, and economic models for Southeastern United States pine forests. World Resource Review. 12(2): 298–320.

Miles, P.D.; Brand, G.J.; Alerich, C.L. [and others]. 2001. The forest inventory and analysis database: database description and users manual. Version 1.0. Gen. Tech. Rep. NC–218. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 130 p.

Nash, B.L.; Davis, D.D.; Skelly, J.M. 1992. Forest health along a wet sulfate/pH deposition gradient in north-central Pennsylvania. Environmental Toxicology Chemistry. 11: 1095–1104.

National Academy of Science. 1992. Rethinking the ozone problem in urban and regional air pollution. Washington, DC: National Academy Press. 500 p.

National Acid Precipitation Assessment Program. 1998. National acid precipitation assessment program biennial report to Congress: an integrated assessment. Silver Spring, MD: National Acid Precipitation Assessment Program. http://www.nnic.noaa.gov/CENR/NAPAP/NAPAP_96.htm. [Date accessed: December 15, 2000].

National Assessment Synthesis Team. 2001. Climate change impacts on the United States: the potential consequences of climate variability and change. Report for the U.S. global change research program. Cambridge, UK: Cambridge University Press. 620 p.

National Atmospheric Deposition Program. 2000. National atmospheric deposition program annual summaries. http://nadp.sws.uiuc.edu/lib/data/99as.pdf. [Date accessed: December 15].

National Oceanic and Atmospheric Administration. 2000. River flooding spreads in Southern States. Press release NOAA 2000-224. http://www.publicaffairs.noaa.gov/releases2000/apr00/noaa00r224.html. [Date accessed: July 20, 2001].

National Research Council Board on Agriculture. 1998. Changing conditions of the forest. In: Forested landscapes in perspective: prospects and opportunities for sustainable management of America's non-Federal forests. Washington, DC: National Academy Press: 57–71.

Negron, J.F. 1998. Probability of infestation and extent of mortality associated with the Douglas-fir beetle in the Colorado Front Range. Forest Ecology and Management. 107: 71–85.

Neilson, R.P.; Drapek, R.J. 1998. Potentially complex biosphere responses to transient global warming. Global Change Biology. 4: 505–521.

North Carolina Department of Environment and Natural Resources. 2001. Southern air principles. Press release. http://daq.state.nc.us/news/pr/2001/files/sap_0801.shtml. [Date accessed: May 10, 2002].

North Carolina General Assembly. 2001. Senate bill 1078. Short title: improve air quality/electric utilities. http://www.ncga.state.nc.us/html2001/bills/allversions/senate/s1078v1.html. [Date accessed: May 10, 2002].

Ollinger, S.V.; Aber, J.D.; Reich, P.B. 1997. Simulating ozone effects on forest productivity: interactions among leaf-, canopy-, and stand-level processes. Ecological Applications. 7(4): 1237–1251.

Paine, R.T.; Tegner, M.J.; Jonson, A.E. 1998. Compounded perturbations yield ecological surprises: everything else is business as usual. Ecosystems. 1: 535–545.

Peart, D.R.; Nicholas, N.S.; Zedaker, S.M. [and others]. 1992. Condition and recent trends in high-elevation red spruce populations. In: Eagar, C.; Adams, B., eds. Ecology and decline of red spruce in the Eastern United States. New York: Springer-Verlag: 125–191.

Peterson, C.J.; Pickett, S.T.A. 1995. Forest reorganization: a case study in an old-growth forest catastrophic blowdown. Ecology. 76: 763–774.

Peterson, Chris J. 2000. Catastrophic wind damage to North American forests and the potential impact of climate change. The Science of the Total Environment. 262: 287–311.

Plantinga, A.J.; Birdsey, R.A. 1993. Carbon fluxes resulting from U.S. private timberland management. Climatic Change. 23: 37–53.

Plantinga, A.J.; Mauldin, T.; Miller, D.J. 1999. An economic analysis of the costs of sequestering carbon in forests. American Journal of Agricultural Economics. 81: 812–824.

Reams, G.G.; Van Deusen, P.C. 1993. Synchronic large-scale disturbances and red spruce growth decline. Canadian Journal of Forest Research. 23: 1361–1374.

Reich, P.B.; Schoettle, A.W.; Stroo, H.F.; Amundson, R.G. 1988. Effects of ozone and acid rain on white pine *(Pinus strobus)* seedlings grown in five soils. III. Nutrient relations. Canadian Journal of Botany. 66(8): 1517–1531.

Reuss, J.O.; Johnson, D.W. 1986. Acid deposition and the acidification of soils and waters. New York: Springer-Verlag. 119 p.

Richardson, C.J.; Sasek, T.W.; Fendick, E.A. 1992. Implications of physiological responses to chronic air pollution for forest decline in the Southeastern United States. Environmental Toxicology and Chemistry. 11(8): 1105–1114.

Rochelle, B.P.; Church, M.R. 1987. Regional patterns of sulfur retention in watersheds of the Eastern U.S.A. Water, Air, and Soil Pollution. 36: 61–73.

Royer, J.F.; Chauvin, F.; Timbal, B. [and others]. 1998. A GCM study of the impact of greenhouse gas increase on the frequency of occurrence of tropical cyclones. Climatic Change. 38: 307–343.

Sampson, R.N.; Brown, S. [and others]. 1993. Terrestrial biospheric carbon fluxes—quantification of sinks and sources of CO_2. Water, Air, and Soil Pollution. 70: 3–15.

Sanchez, F.G. 1998. Soil organic matter and soil productivity: searching for the missing link. In: Mickler, R.A.; Fox, S., comps., eds. The productivity and sustainability of southern forest ecosystems in a changing environment. New York: Springer-Verlag: 543–556.

Sarmiento, J.L.; Wofsy, S.C. 1999. A U.S. carbon cycle science plan: a report of the carbon and climate working group. Washington, DC: U.S. Global Change Research Program. 69 p.

Schichtel, B.A.; Falke, S.R.; Vasconcelos, L.A. 1996. Evaluation of the 1990 baseline ozone exposure estimates used in EPA's economic benefits assessment of alternative secondary ozone standards. Pap. 99–375. St. Louis, MO: Washington University, Center for Air Pollution Impact and Trend Analysis (CAPITA). http://capita.wustl.edu/CAPITA/CapitaReports/Awma99/O3ExpEvl/O3ExpEvl.htm. [Date accessed: December 2000].

Schichtel, B.A.; Husar, R.B. 1999. Eastern U.S. transport climatology during average, high and low ozone days. 98-A884. St. Louis, MO: Washington University, Center for Air Pollution Impact and Trend Analysis (CAPITA). http://capita.wustl.edu/CAPITA/Awma98/HTTP/98_A884.htm. [Date accessed: December 2000].

Shortle, W.C.; Smith, K.T. 1988. Aluminum-induced calcium deficiency syndrome in declining spruce. Science. 240: 1017–1018.

Skelly, J.M.; Hildebrand, E. 1995. Occurrence and severity of ozone injury on sensitive hardwood species in Shenandoah National Park. Tech. Rep. NPS/MARSHEN/NRTR–95/068. Washington, DC: U.S. Department of the Interior, National Park Service. 315 p.

Skog, K.E.; Nicholson, G.A. 1998. Carbon cycling through wood products: the role of wood and paper products in carbon sequestration. Forest Products Journal. 48: 75–83.

Smith, J.E.; Heath, L.S. 2000. Considerations for interpreting probabilistic estimates of uncertainty of forest carbon. In: Joyce, Linda A.; Birdsey, Richard, eds. The impact of climate change on America's forests: a technical document supporting the 2000 USDA Forest Service RPA Assessment. Gen. Tech. Rep. RMRS–GTR–59. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 18–44. Chapter 7.

Southern Appalachian Man and the Bioshpere. 1996. Southern Appalachian assessment aquatics technical report. Rep. 2 of 5. Atlanta: U. S. Department of Agriculture, Forest Service, Southern Region. 166 p.

Southern Appalachian Mountains Initiative. 2001. Interim report. Asheville, NC: Southern Appalachian Mountains Initiative. 20 p.

Stocks, B.J. [and others]. 1998. Climate change and forest fire potential in Russian and Canadian Boreal forests. Climatic Change. 38: 1–13.

Swank, W.T.; Vose, J.M. 1997. Long-term nitrogen dynamics of Coweeta forested watersheds in the Southeastern United States of America. Global Biogeochemical Cycles. 11(4): 657–671.

Taylor, G.E. 1994. Role of genotype in the response of loblolly pine to tropospheric ozone—effects at the whole tree, stand, and regional level. Journal of Environmental Quality. 23(1): 63–82.

Teskey, R.O. 1996. Synthesis and conclusions from studies of southern commercial pines. In: Fox, S.; Mickler, R.A., eds. Impact of air pollutants on southern pine forests. Ecological Studies 118. New York: Springer-Verlag: 467–490.

Thompson, A.M. 1992. The oxidizing capacity of the Earth's atmosphere: probable past and future changes. Science. 256: 1157–1165.

Twilley, R.R.; Barron, E.J.; Gholz, H.L. [and others]. 2001. Confronting climate change in the gulf coast region: prospects for sustaining our ecological heritage. Cambridge, MA: Union of Concerned Scientists; Washington, DC: Ecological Society of America. [Number of pages unknown].

U.S. Department of Agriculture, Forest Service, Forest Health Protection Program. 2000. America's forests: 1999 health update. Agric. Inf. Bull. 757. [Washington, DC]: U.S. Department of Agriculture, Forest Service, State and Private Forestry. http://www.fs.fed.us/foresthealth/fh_update/update99/index.html. [Date accessed: October 19].

U.S. Department of Energy, Office of Science, Office of Fossil Energy. 1999. Carbon sequestration research and development. Available from: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. http://www.ornl.gov/carbon_sequestration/carbon_seq.htm. [Last accessed: December 18, 2000].

U.S. Environmental Protection Agency. 1996. Air quality criteria for ozone and related photochemical oxidants. Rep. EPA–600/P–93/004bF. Research Triangle Park, NC: National Center for Environmental Assessment, Office of Research and Development, Office of Air Quality Planning and Standards. [Number of pages unknown].

U.S. Environmental Protection Agency. 1997a. Acid rain program. http://www.epa.gov/airmarkets/arp/index.html. [Date accessed: December 15, 2000].

U.S. Environmental Protection Agency. 1997b. National ambient air quality standards for particulate matter: final rule. Fed. l Reg. 62: 138 (38651), July 18, 1997, Doc. 97–18577. http://fr.cos.com/cgi-bin/getRec?id=19970718a132. [Date accessed: December 11, 2000].

U.S. Environmental Protection Agency. 1998. Ozone research needs to improve health and ecological risk assessments. EPA/600/R–98/031. Research Triangle Park, NC: National Center for Environmental Assessment, Office of Research and Development. [Number of pages unknown].

Walsh, K.; Pittock, A.B. 1998. Potential changes in tropical storms, hurricanes, and extreme rainfall events as a result of climate change. Climatic Change. 39: 199–213.

Whelan, R.J. 1995. The ecology of fire. New York: Cambridge University Press. 346 p.

Wolff, G.T.; Lioy, P.J.; Wight, G.D. [and others]. 1977. An investigation of long-range transport of ozone across the Midwestern and Eastern United States. Atmospheric Environment. 11(9): 797–802.

Photo courtesy Bill Lea, National Forests in North Carolina

AQUATIC

What are the history, status, and likely future of water quality in southern watersheds?

Chapter 19: Water Quality in the South

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Key Findings

- Significant water-quality impairment, forest loss, and wetland loss have occurred in the South since the time of European settlement; however, water quality has generally improved since the passage of the Clean Water Act in 1972.
- Based on a national watershed characterization program, approximately 30 percent of the South has relatively good water quality, 36 percent has moderate water-quality problems, and 15 percent has more serious water-quality problems; approximately 19 percent of the South, primarily in western Texas, does not have sufficient information to provide a characterization of the status of water quality.
- The leading causes (pollutants) of water-quality impairment in the South from 1988 to 1998 were siltation (sedimentation), pathogens (bacteria), and nutrients (nitrogen and phosphorous).
- The leading sources of water-quality impairment in the South from 1988 to 1998 were agriculture and urbanization; silviculture ranked 9th out of the 10 major sources of impairment during this time.
- Approximately 70 percent of all pollution came from nonpoint sources.
- Southern forests are a vital factor in maintaining and improving water quality in the South. Forested watersheds have consistently been shown to have lower sediment and nutrient yields with better aquatic biological conditions than nonforested watersheds.
- The primary factor affecting the future of water quality in the South is control of nonpoint-source pollution from agriculture and urbanization, primarily urban sprawl.
- The future of water quality in the South is highly dependent on the success of future mandates and programs such as the Clean Water Action Plan and Unified Watershed Assessment restoration priorities, as well as citizen involvement in watershed protection, including public education and voluntary initiatives.
- Agencies responsible for monitoring water quality in the South should develop standard assessment and reporting criteria for determining the causes and sources of impairment and describing the level of confidence in the classification.

Introduction

Approximately 935,000 miles of rivers and streams flow across the South. These waterways are important in defining the landscape and in providing habitat for many of the South's plants and animals. They also have significant economic values that are of great importance but are often overlooked. Rivers, lakes, estuaries, and wetlands provide flood protection and support industry. Recreation activities such as fishing, boating, and rafting generate jobs, economic benefits, and tax revenue to the region. In addition, much of the South's drinking water is obtained from surface-water sources.

As the South continues to enjoy strong economic growth, increasing demands and threats are placed upon our river systems. These threats directly affect the natural and historical heritage of our rivers, and, ultimately, public health and quality of life. Threats are varied and include pollution and impacts from many sources, including residential development, construction, municipal and industrial stormwater runoff, agricultural runoff (containing sediments, pesticides, herbicides, and fertilizers), deforestation, impoundments, channel alteration, and introduction of exotic species.

In recognition of these threats, there is a growing public awareness of the importance of aquatic resources and the need to manage land to protect, maintain, and restore water quality. All Southern States have adopted a watershed-based approach to controlling water pollution and improving water quality. A watershed is an area of land in which water flows across the land surface and drains into a particular marsh, stream, river, or lake. Watersheds can vary in size from a few acres to thousands of acres (U.S. Environmental Protection Agency 2001d). A watershed management approach accounts for a watershed's unique needs and recognizes that water quality is a function of not just one stream, but rather the entire watershed.

This chapter provides an overview of the history, status, regulatory controls, and likely future of water quality in southern watersheds. The relative impacts of land uses on water quality over time are evaluated, as are the ways in which point and nonpoint sources of pollution have influenced water quality. The original intent of this chapter was to describe water quality only in forested watersheds. However, in order to address the range of topics described previously and to respond to specific public comments about this chapter, all watersheds are included in this evaluation. The result is a more comprehensive overview of water quality in the South. A discussion of the role of forests in protecting water quality in the South is also included in the section: "Role of forests in protecting water quality."

Methods

Information presented is limited to published literature, other regulatory reports, and personal interviews conducted with water-quality experts in the South. The status of water quality was examined and reported at various scales across the South, including the whole region, individual States, ecological regions, and individual watersheds.

There are numerous linkages and areas of overlap between this chapter and other chapters in this Assessment. To avoid redundancy and enhance integration with other Assessment questions, the reader is referred to other chapters where information is presented in greater detail.

Data Sources

Spatial Data

The United States is divided and subdivided into successively smaller hydrologic units. Four levels are recognized: (1) regions, (2) subregions, (3) accounting units, and (4) cataloging units. These hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification (U.S. Geological Survey 2001a).

Individual watersheds were delineated using the U.S. Geological Survey (USGS) cataloging unit classification system, or eight-digit HUC, in which the last digit represents the smallest consistent watershed size throughout the South. Watershed information was summarized for all watersheds that are wholly or partially located in the 13-State study area. Using this system, the South is divided into 672 watersheds. The average size of these watersheds at this scale is approximately 810,000 acres.

Ecological regions were delineated at the ecological province, following the National Hierarchical Framework of Ecological Units (ECOMAP 1993). There are 11 ecological provinces in the South. A complete description of the ecological provinces in the South is included in chapter 16.

Land Use Data

The primary source of land use data, particularly forest cover, for this chapter was the Forest Inventory and Analysis (FIA) plot-level data assembled for this Assessment (U.S. Department of Agriculture, Forest Service 2001). Information contained in the FIA database is derived from a series of permanent plots across the South and is typically reported at the State and county level. A complete discussion of the FIA Eastwide database is provided by Hansen and others (1992).

The most current survey data from each State were aggregated across the South to create a current survey for the South (representing the 1990s). Information on the most recent survey for each State is included in chapter 16. Individual plots were assigned an eight-digit HUC and aggregated at the watershed level. Land uses from the FIA database representing forested land were selected and summarized by individual watershed to determine the percentage of forest in each watershed. That percentage was calculated by dividing the forest area by the total watershed area.

Water-Quality Data

The following sources of water-quality data were used to compile this chapter:

- Literature surveys.
- Interviews with The University of Georgia (UGA) staff.
- U.S. Environmental Protection Agency (USEPA) National Water Quality Inventories, in reports to Congress.
- USEPA Index of Watershed Indicators.
- Unified Watershed Assessment data from each of the 13 Southern States.
- USGS National Water Quality Assessment (NAWQA) Program Studies.

Results

History of Water-Quality Conditions in the South

This section is confined to key points about the history of water quality in the South. A discussion of the history of southern forests and land use change in the South is included in chapters 6 and 24.

Little information is available on water quality in the South prior to the 20th century. Erosion resulting from Native American transportation and agricultural practices has been characterized as minimal (Binkley and Brown 1993, Sedjo 1991). Causes of erosion during this period included fires, mass soil movement, natural stream erosion, and animal trails. For example, migration of buffalo was correlated with an increase in stream turbidity (Trimble 1974).

Early descriptions repeatedly characterized streams as clear and dark as opposed to the brown or red color that now dominates southern streams (Trimble 1974). Early explorers described a shiny substance in streams, which may have indicated the presence of mica (Trimble 1974). Mica is no longer abundant in the majority of streams in the Southeast, presumably due to manmade erosion of upland soils into streams. The average soil loss in the North Carolina Piedmont was less than one-tenth inch per 1,000 years prior to European settlement. Current rates of soil loss from clean cultivated land are 80 to 300 inches per 1,000 years (Trimble 1974).

Settlement by Europeans resulted in large-scale ecological changes that continue to affect water quality (Trimble 1974). Throughout the early settlement period, water quality declined as land cover shifted from mature forests to agricultural fields (Trimble 1974). Sedimentation and erosion were the primary causes of water-quality impairment. It has been estimated that an average of 5.9 inches (15 cm) of soil have been lost in the Southeast due to erosion since the time of European settlement (Binkley and Brown 1993). Cotton, tobacco, and small plots of corn dominated agricultural crops through 1860. Cotton plantations were the primary source of water-quality impairment during this period (Trimble 1974).

The period between 1860 and 1920 was the most destructive in the South with regard to water quality due to widespread clearing of forests for fuel, timber, wood products, and crops (Trimble 1974). Forest clearing without erosion control measures resulted in increased sedimentation and severe water-quality impairment (Mac and others 1998). Logging activities peaked in 1909 and remained high until 1920. By 1920, only a small area of virgin forest remained. After the Civil War, agriculture continued to be the most important land use in the South. Increased soil erosion rates due to inadequate conservation practices and increased use of fertilizers accelerated the degradation of water quality (Trimble 1974). Southern rivers filled with sediments from upland soils.

Comprehensive water-resource research was largely initiated during this period. The first watershed experiment, called the Wagon Wheel Gap study, was conducted in 1909. This Colorado study focused on the effects of deforestation on the volume and timing of streamflow, soil erosion, and sediment loading (Megahan and Hornbeck 2000).

Between 1920 and 1972, people migrated to cities as industry became the dominant force in the United States economy. Less wood was used for fuel and roads, resulting in a decrease in the demand for wood (Sedjo 1991). Due to this decreased demand, logging and land-clearing activities were significantly reduced. Therefore, adverse effects on water quality from these activities also declined.

The effect of agricultural land use practices became evident in the 1930s with the onset of the Great Depression (Mac and others 1998). Losses of fertile soil due to the intensity and types of agriculture practices, as well as drought conditions, resulted in the Dust Bowl of the 1930s and the abandonment of farmland (Meyer 1995). Soil erosion during this time period adversely affected water quality, primarily due to sedimentation of rivers and streams.

Draining of wetlands, which serve as filters for surface-water runoff, was another contributing factor to water-quality impairment. Between 1950 and 1970, 11 million acres of wetlands were lost in the United States (Meyer 1995). A complete discussion of the history of forested wetlands in the South is provided in chapter 20. Flooding was also a problem during this period, and the Flood Control Act of 1936 brought about the modification of major rivers, such as the Mississippi. River channels were widened and dredged to facilitate navigation. These practices had devastating effects on many aquatic species, by removing or covering benthic habitat. A complete discussion of aquatic species and habitats is included in chapter 23.

In the late 19th and early 20th centuries, waterborne disease occurred in urban centers as populations came into contact with water bodies contaminated with sewage. Diseases such as cholera were transmitted through inadequate disposal of human waste, and typhoid fever outbreaks occurred as cities began to develop (Chase 1952, Cowdrey 1996). As a result, sanitary engineering (later called environmental engineering) developed technologies to reduce waterborne illnesses by treating sewage prior to discharging it into water bodies (Chase 1952). Industrialization in the South also created water-quality problems during this period. The petrochemical, paper, and automotive industries are a few of the industries that impacted water quality by discharging industrial wastes directly into water bodies (Cowdrey 1996).

Pesticide use increased dramatically after World War II. Overspraying resulted in numerous instances of harmful levels of pesticides in soil and water. Toxic compounds such as dichlorodiphenyltrichloroethane (DDT) were used without restrictions. In 1962, Rachel Carson's "Silent Spring" highlighted the effects of DDT, which include contamination of water supplies and thinning of predatory bird eggshells. In 1972, the use of DDT was banned (Cowdrey 1996).

As a better understanding of the interdependence of water quality and land use practices was developed, legislation at local, regional, and national levels was passed to address the management and preservation of natural resources. According to the USEPA, only a third of the Nation's waters were safe for fishing and swimming in 1972 (U.S. Environmental Protection Agency 2001a). In response to the situation, the Federal Water Pollution Control Act, or Clean Water Act (CWA), was passed in 1972. This act significantly changed the way the Federal Government and individual States regulated and reported on water quality. In addition, State and local mandates were developed to regulate sources and causes of water-quality impairment on a local level. Land-disturbance activities and urban development are subject to regulations and guidelines at the State and local level via sedimentation and erosion-control management plans, zoning, permits, and implementation of best management practices (BMPs). The CWA and other laws and regulations that affect water quality in the United States are summarized and discussed in detail in chapter 8, primarily as they relate to silvicultural practices.

Subsequent to the passage of the CWA, a comprehensive analysis of water quality in rivers was conducted (Smith and others 1987). This study utilized data from the National Stream Quality Accounting Network (NASQAN) and the National Water Quality Surveillance System (NWQSS). In general, results of this study indicated that point-source pollution had decreased on a national scale, and nonpoint-source pollution had increased since passing of the CWA (Smith and others 1987). A complete discussion of point and nonpoint sources of pollution is included in the section "National Water Quality Inventories: leading sources of impairment (1988-98)."

In the South, decreases in bacteria associated with municipal wastewater discharges were noted, especially in parts of the Gulf of Mexico, central Mississippi, and Arkansas. However, localized increases in bacteria were noted in association with point-source livestock waste discharges. A dramatic increase in suspended sediment, nutrients, phosphorous, and nitrate was observed due to increased fertilizer applications, other agricultural practices, and high soil erosion rates. In addition, atmospheric deposition was positively correlated with increases in nitrate concentrations, especially in forested basins. In contrast, a decrease in phosphorous concentrations was noted in the upper Mississippi Valley.

An increase in contaminants such as metals was observed primarily due to fossil fuel combustion, metal manufacturing, pesticides, and herbicides. However, a widespread decrease in lead concentrations was observed due to a 67-percent drop in leaded gasoline consumption (Smith and others 1987).

Current Status of Water Quality in the South

Concerns about water quality in the South have engendered proactive research, monitoring, and control programs. In addition, public and private stakeholders are supporting the development of comprehensive watershed assessments and related studies. The goal of these programs and studies is to assess and improve water quality in the United States, including the South. Two primary programs have been developed to report information on water quality: (1) National Water Quality Inventories, and (2) USEPA Index of Watershed Indicators (IWI). The National Water Quality Inventories provide information at the regional and State levels, and the IWI program provides information about water quality in individual watersheds (USGS eight-digit HUC). These and other regional assessment programs such as the USGS NAWQA and Southern Appalachian Assessment are summarized in this section.

National Water Quality Inventories—To assess progress toward the goals of the CWA, States, tribes, and other jurisdictions adopt water-quality standards, which must be approved by the USEPA. Water-quality standards have three elements (U.S. Environmental Protection Agency 2000b):

1. Designated uses: All waters of the United States are required by law to be designated for beneficial uses. Examples include drinking water supply, contact recreation (swimming), and support of warm- and coldwater fisheries. States are responsible for assigning designations and can designate multiple uses for the same water body.

2. Criteria: Scientists establish criteria necessary to protect the designated uses. Criteria can include chemical-specific thresholds that protect fish and humans from adverse health effects as well as biological and habitat conditions.

3. Antidegradation policy: The antidegradation policy is intended to prevent waters from deteriorating from their current conditions. Therefore, States cannot change a water body's designated use(s) to lower water-quality standards without extensive justification.

The status of the Nation's waters is determined by assessing the degree to which the States' water-quality standards are met (U.S. Environmental Protection Agency 1994). States, tribes, and other jurisdictions are required and/or encouraged, under Section 305(b) of the CWA, to submit a report to the USEPA on the status of their water bodies. For purposes of this section, discussion is limited to State 305(b) reports and does not include reports from tribes or other jurisdictions. States are required to submit updated 305(b) reports once every 2 years. According to Section 305(b) of the CWA, reports should include the following:

- A description of water quality for all navigable waters in the State.
- An analysis of the extent to which all navigable waters in the State provide for the protection and propagation of shellfish, fish, and wildlife, and allow recreational activities in and on the water.
- An analysis of the extent to which the elimination of the pollutants has been or will be achieved to meet water-quality standards.
- Recommendations of actions needed to achieve the water-quality standard.
- An estimate of the extent of environmental impact and the economic and social costs and benefits associated with achieving the water-quality standard, and the date by which the water-quality standard will be achieved.
- A description of the nature and extent of nonpoint sources of pollutants and recommendations of programs to control these sources, including costs to implement such controls.

The CWA requires States to assess the degree to which waters meet adopted water-quality standards. In order to meet this requirement, States examine two types of data: monitored data and evaluated data. Monitored data supply quantitative information including field measurements that are not more than 5 years old, such as biological, habitat, toxicity, and/or physical/chemical conditions in water bodies, sediments, and fish tissues. Evaluated data are quantitative and/or qualitative information frequently used to fill data gaps. Evaluated data include field measurements that are more than 5 years old, estimates generated using land use and source information, predictive models, and surveys from fish and game biologists (U.S. Environmental Protection Agency 2000b). An example of this process follows: The degree to which the Georgia water-quality standard for streams classified as fishable must be assessed. The standard is that fishable streams must contain less than 1,000 fecal coliform bacteria per 100 ml of water for the months of November through April (Georgia Water Quality Control Act 391-3-6.03). If monitored or evaluated data indicate that fecal coliform exceeds this standard, the fishable use criterion is not supported.

Depending on the degree to which designated uses are supported, States place assessed waters into the following categories (U.S. Environmental Protection Agency 2000b):

1. Fully supporting overall use: A water body that meets all of the established criteria for designated beneficial uses.

2. Threatened overall use: A water body that fully supports all of its designated beneficial uses but is in danger of not fully supporting one or more of the uses.

3. Partially supporting overall use: A water body that does not meet all of the established criteria for one or more of its designated beneficial uses.

4. Not supporting overall use: A water body that does not meet any of the established criteria for one or more of its designated beneficial uses.

5. Not attainable: A water body for which one or more designated beneficial uses is not achievable due to natural conditions or human activity that cannot be reversed without imposing widespread economic and social impacts. This category is derived by a State-conducted use-attainability study.

Impaired waters are defined as any water body that is classified as partially supporting or not supporting overall use. Impaired water bodies are summed, and the State reports the amount of total impaired waters.

The USEPA compiles the information in State 305(b) reports and submits a summary report entitled "National Water Quality Inventory Report to Congress" (National 305(b) Reports). These reports are the principal vehicle for informing Congress and the public about general water-quality conditions in the United States. Discussions and data for this chapter are based on the information included in the National 305(b) Reports.

National Water Quality Inventories: general trends in water quality (1988-98)—The National 305(b) Reports from 1988 to 1998 were evaluated to identify recent trends in water quality in the South (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b). These reports include summaries of water quality for rivers and streams, lakes, reservoirs, ponds, tidal estuaries, shoreline waters, coral reefs, wetlands, and ground water in individual States. In this chapter, only water quality of rivers and streams in the South is reported. The National 305(b) Reports do not describe the health of all rivers and streams in the South because the States have not comprehensively assessed all their waters. Due to funding and monitoring constraints, States only assess a subset of total waters. Therefore, the health of only those portions of rivers and streams assessed and reported in individual State water-quality inventories are summarized in this chapter.

Southern States assessed a total of approximately 149,260 river miles in 1988 and approximately 231,600 river miles in 1998 (U.S. Environmental Protection Agency 1990, 2000b). The term "river miles" is used interchangeably with "river and stream miles" in this chapter. Assessed river miles increased by 55 percent over this 10-year period. The 231,600 assessed river miles in 1998 represent approximately 25 percent of the South's total river and stream miles, which is consistent with the percent assessed nationwide in 1998. This amount is considerable because only approximately 470,000 river miles in the South are perennial waters (flow year round). The remaining 463,000 river miles are intermittent or ephemeral, which means they are dry for some or most of the year.

As described previously, each State reports the assessed river miles as fully supporting, partially supporting, or not supporting overall use. The last two categories represent impaired river miles. From 1988 to 1998, 9 of the 13 Southern States reported an increase in impaired river miles. The percentage of river miles that were impaired rose from 26 to 45 during the 10-year period. In 1998, Southern States reported that 55 percent of the 231,600 assessed river miles fully support all of their uses. This percentage is slightly lower than the nationwide percentage in 1998 (65 percent). Of the fully supporting river miles, 10 percent (approximately 23,700 river miles) were considered threatened. These threatened waters may need special attention and additional monitoring to prevent further deterioration. Some form of pollution or habitat degradation impairs the remaining 45 percent (103,441 river miles) of the assessed river miles.

The designation of river miles as being impaired is a complicated process that varies among reporting cycles and States. In many cases, States do not use directly comparable criteria and monitoring strategies to measure their water quality. Therefore, States with strict criteria for defining healthy waters are more likely to report that a high percentage of their waters are not fully supporting designated uses. Similarly, States with comprehensive monitoring programs are more likely to identify more water-quality problems. Because of these issues, it is likely that the increase in impaired miles from 1988 to 1998 is related to the overall increase in assessed river miles. As a result, one cannot assume that water quality is worse now than in 1988 just because an individual State reports a higher number or percentage of impaired waters. A more thorough discussion of the data limitations of the 305(b) reports is included in section "National Water Quality Inventories: Limitations of the National 305(b) Reports."

National Water Quality Inventories: leading causes of impairment (1988-98)—Each State identifies causes and sources of impairment of rivers and streams in order to determine where improvements are needed, and to assess the effectiveness of current water-quality programs and protection policies. Causes of impairment are pollutants, practices, or processes that

Table 19.1—Common causes of pollution summarized from National Water Quality Inventory Reports

Cause of impairment	Description of cause
Nutrients	Nitrates found in sewage and fertilizers and phosphates found in detergents and fertilizers.
Siltation (sedimentation)	Wash off plowed fields, construction and logging sites, urban areas, strip-mined land, and eroded stream banks.
Pathogens (bacteria)	Inadequately treated sewage, storm water drains, septic systems, runoff from livestock pens, and boats that dump sewage.
Organic material	Sewage, leaves and grass clippings, and runoff from livestock feedlots and pastures.
Metals	Industrial discharges, runoff from city streets, mining activities, and leachate from landfills.
Pesticides and herbicides	Runoff from croplands, lawns, and termite control.
Habitat modification	Grazing, farming, channelization, dam construction, and dredging.

Source: U.S. Environmental Protection Agency 1994.

result in numeric or narrative support criteria being exceeded. Specific causes of impairment may include chemical contaminants (such as polychlorinated biphenyls, dioxin, and metals), physical conditions (such as temperature), and biological conditions (such as aquatic weeds) (U.S. Environmental Protection Agency 1998a). A water body may be affected by multiple causes. Descriptions of the common causes of pollution included in the National 305(b) Reports are provided in table 19.1. The leading causes of pollution in southern rivers and streams from 1988 to 1998 were siltation (sedimentation), pathogens (bacteria), nutrients, and organic enrichment.

National Water Quality Inventories: leading sources of impairment (1988-98)—Once the cause of impairment is identified, the States report the estimated source of the impairment. There are two broad categories of sources of pollution: (1) point-source pollution and (2) nonpoint-source pollution. The fundamental difference between these two categories is the manner in which the pollutant reaches the water body, which is often directly related to land use. The current statutory definition of a point source is as follows (Water Quality Act, Sec. 502-514, U.S. Congress, 1987):

The term "point source" means any discernible, confined, and discrete conveyance, including, but not limited to any pipe, ditch, channel, tunnel, conduit, well discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Research conducted in the late 1970s indicated that over half of all water pollution was due to nonpoint sources (Neary and others 1989). Therefore, the CWA was amended in 1987 to place more emphasis on proactive approaches for controlling nonpoint-source pollution (Novotny and Olem 1994). Nonpoint-source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, or seepage. Descriptions of the common point and nonpoint sources of pollution identified in the National 305(b) Reports are provided in table 19.2. As is the case with causes of impairment, a river mile or water body may be affected by multiple sources.

Table 19.2—Common sources of pollution summarized from National Water Quality Inventory Reports

Source of impairment	Description of source
Point sources	
Municipal	Publicly owned sewage treatment plants that may receive indirect discharges from industrial facilities or businesses.
Storm sewers/ urban runoff[a]	Runoff from impervious surfaces including streets, buildings, lawns, and other paved areas that enters a sewer, pipe, or ditch before discharge into surface waters.
Industrial	Pulp and paper mills, chemical manufacturers, steel plants, textile manufacturers, and food processing plants.
Land disposal[a]	Leachate or discharge from septic tanks, landfills, and hazardous waste sites.
Nonpoint sources	
Agriculture	Crop production, pastures, rangeland, feedlots, and other animal holding areas.
Hydrologic/ habitat modification	Channelization, dredging, dam construction, flow regulation; removal of riparian vegetation, streambank modification, drainage/filling of wetlands.
Resource extraction	Mining, petroleum-drilling, runoff from mine tailing sites.
Construction	Land development, road construction.
Silviculture	Forest management, tree harvesting, logging road construction.
Natural	Non-man-induced impacts, such as floods, hurricanes, leachate from naturally occurring metals, and wildlife.

[a] Storm sewers/urban runoff and land disposal include both point and nonpoint sources.
Source: U.S. Environmental Protection Agency 1998a.

A source of pollution is often the land use practice that generates a reported cause of impairment; therefore, causes and sources of impairment are interlinked. One particular cause may originate from multiple sources. For example, sedimentation can originate from agricultural practices, urban stormwater runoff, and/or road construction sites. Similarly, one particular source may generate multiple causes or pollutants. For example, silvicultural practices can generate sedimentation, nutrient loading, and pesticide inputs. The interconnection between causes and sources is summarized in table 19.3.

The 10 leading point and nonpoint sources of impairment for rivers and streams in the South from 1988 to 1998 are depicted in figure 19.1. The relative contributions of point and nonpoint sources of pollution in rivers and streams in each of the Southern States are shown in figure 19.2. During this time, nonpoint sources contributed annually almost 70 percent of the total pollution to impaired rivers

Table 19.3—Interrelationship between common sources and causes of pollution

Source of impairment	Siltation (sediment)	Pathogens (bacteria)	Nutrients[a]	Organic enrichment	Pesticides	Metals	Habitat modification
Point sources							
Municipal		X	X	X		X	
Storm sewers/ urban runoff[b]	X				X	X	
Industrial	X	X	X	X	X	X	X
Land disposal[b]		X	X	X		X	
Nonpoint sources							
Agriculture	X	X	X	X	X		X
Hydrologic/habitat modification	X		X	X	X		X
Resource extraction	X					X	X
Construction	X						
Silviculture	X		X	X	X		X
Natural	X	X	X	X		X	X

[a] Nutrients include nitrogen and phosphorous.
[b] Storm sewers/urban runoff and land disposal include both point and nonpoint sources.
Source: U.S. Environmental Protection Agency 2000b.

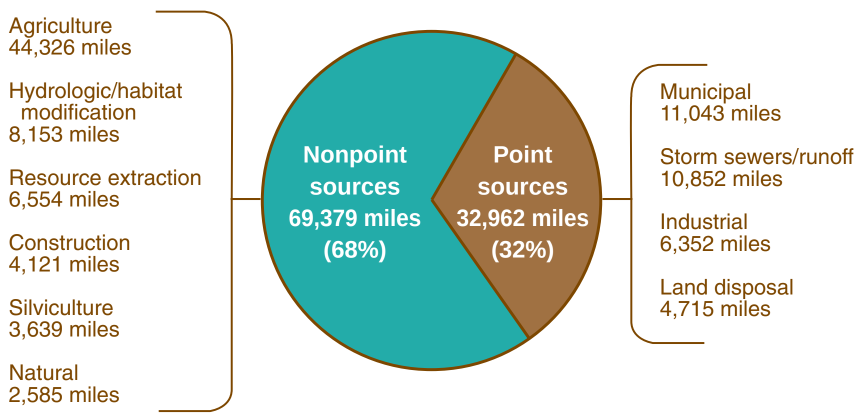


Figure 19.1—Annual average contribution of point and nonpoint sources of pollution to impaired river miles from 1988 to 1998 in the South (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b).

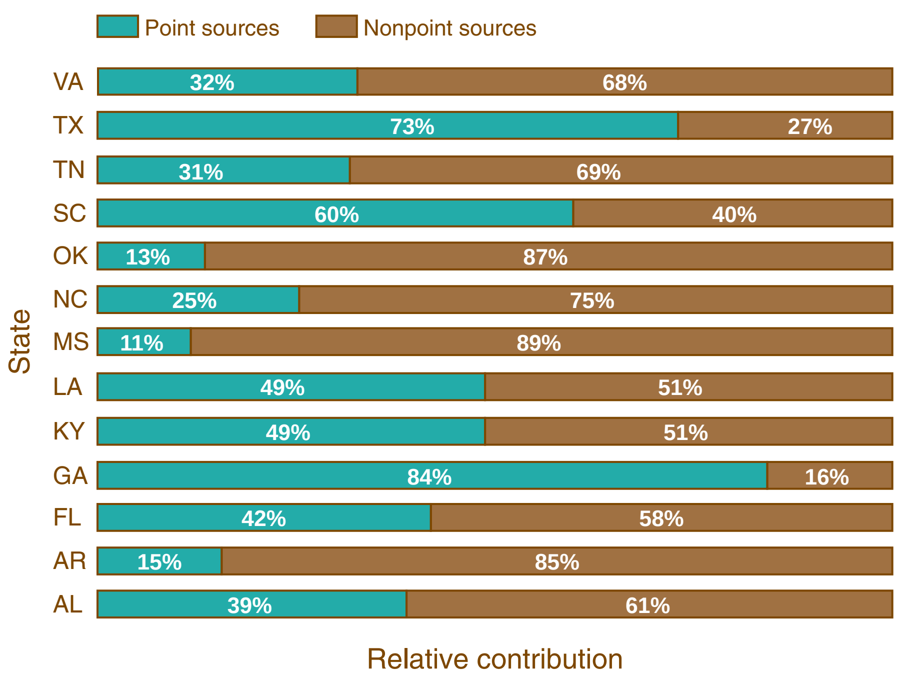
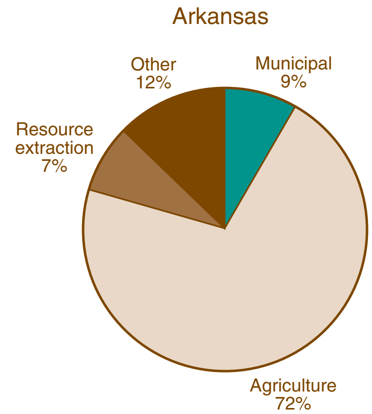
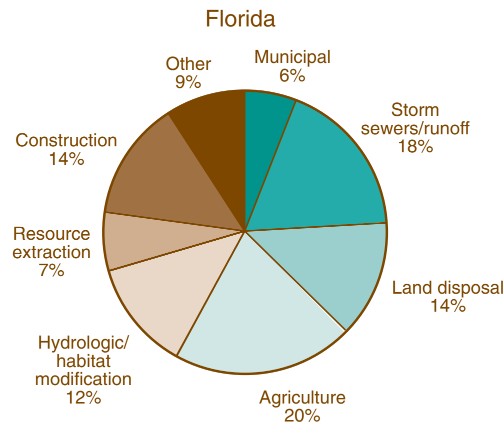


Figure 19.2—Relative percent contribution of point and nonpoint sources of pollution to impaired river miles from 1988 to 1998 (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b).

and streams. In the South, as well as nationwide, agricultural activities, such as crop production and animal operations, were the most widespread sources of pollution in assessed rivers and streams. Agriculture accounted for almost half of the total pollution, greater than all point-source discharges combined. After agriculture, the States reported that municipal treatment plants, storm sewers/urban runoff, and hydrologic/habitat modification were the most common sources of impairment during this 10-year timeframe. Silviculture ranked 9th out of the 10 major sources of impairment during this time. Each of the leading sources of impairment is grouped into major land use practices, and the impacts of these practices are discussed in the section "Land Use Impacts on Water Quality."

The leading sources of impairment for rivers and streams in individual Southern States from 1988 to 1998 are shown in figure 19.3 and reported in table 19.4. With the exception of Georgia and Texas, agricultural activities were the leading sources of pollution in each State during this time. Storm sewer discharges and urban runoff were the largest sources of pollutants in Georgia, and municipal discharges were the largest source of pollutants in Texas. The designation of river miles as being impaired by a specific source is a complicated process that varies among reporting cycles and States. Data limitations of the 305(b)





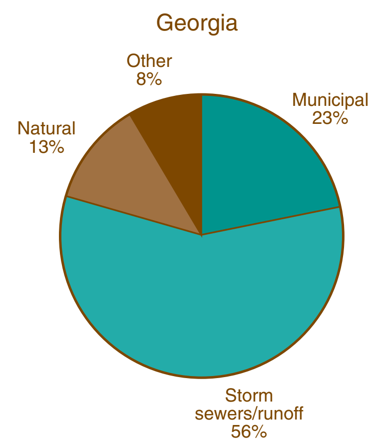
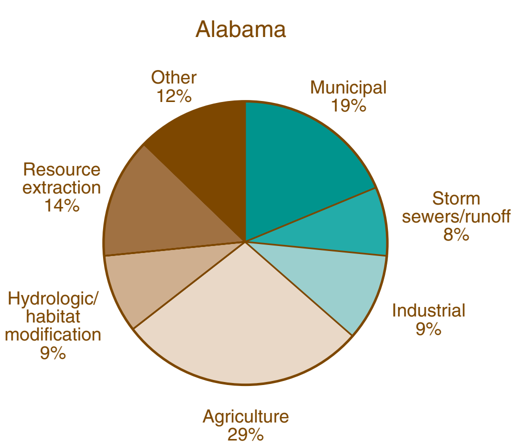
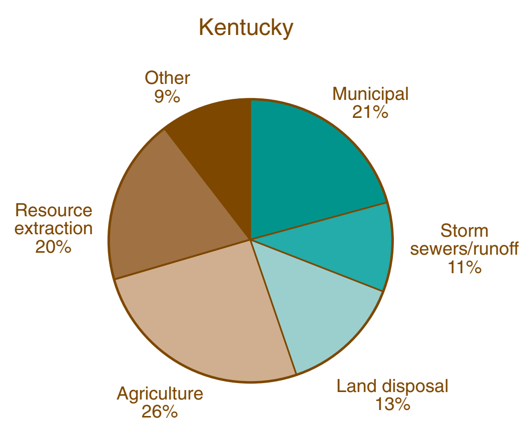


Figure 19.3—Leading sources of impairment of rivers and streams in Southern States from 1988 to 1998 (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b).





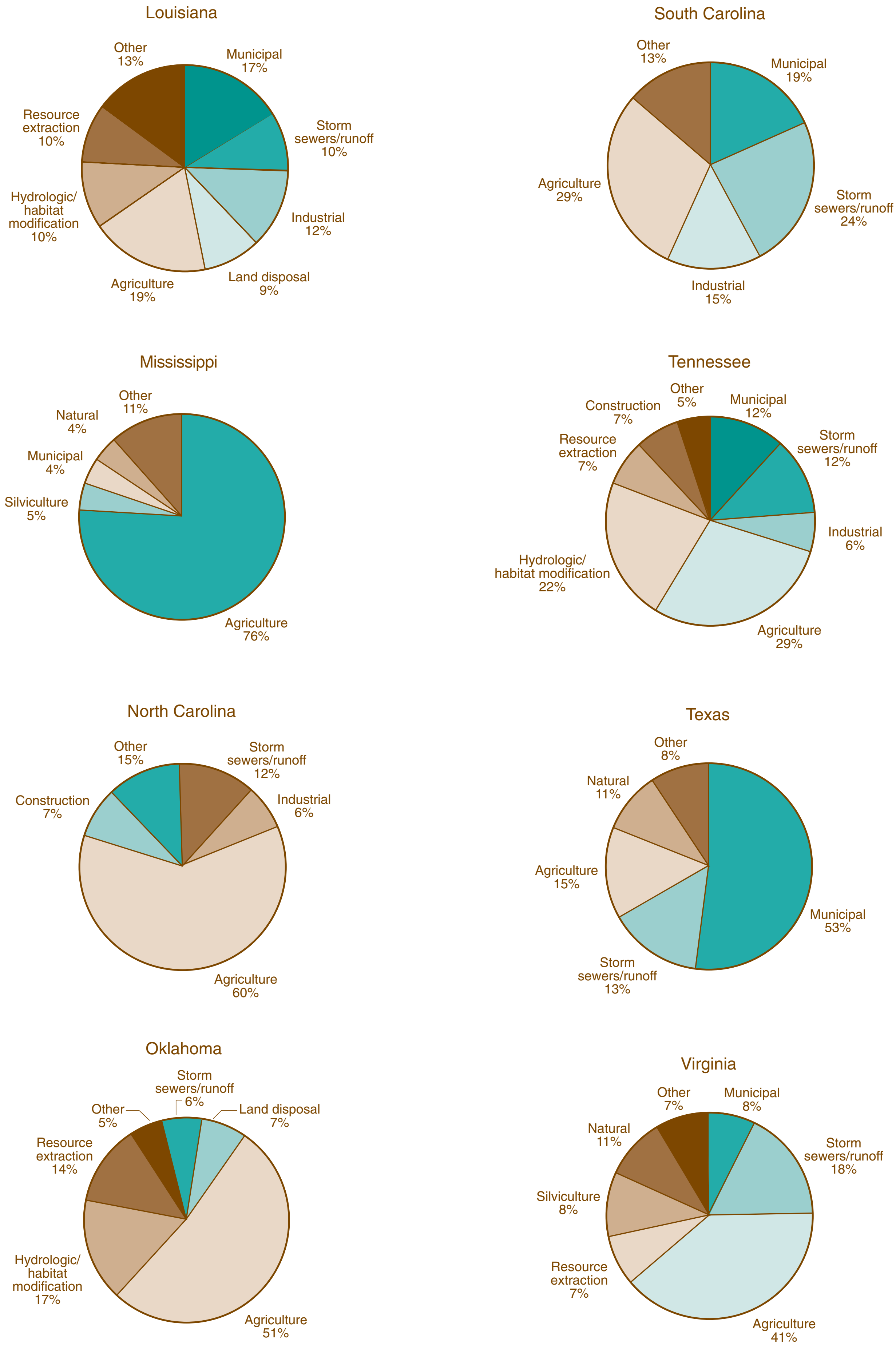

Louisiana
Other 13%
Municipal 17%
Storm sewers/runoff 10%
Industrial 12%
Land disposal 9%
Agriculture 19%
Hydrologic/ habitat modification 10%
Resource extraction 10%
South Carolina
Other 13%
Municipal 19%
Storm sewers/runoff 24%
Industrial 15%
Agriculture 29%
Mississippi
Other 11%
Natural 4%
Municipal 4%
Silviculture 5%
Agriculture 76%
Tennessee
Other 5%
Municipal 12%
Construction 7%
Resource extraction 7%
Storm sewers/runoff 12%
Industrial 6%
Hydrologic/ habitat modification 22%
Agriculture 29%
North Carolina
Other 15%
Storm sewers/runoff 12%
Construction 7%
Industrial 6%
Agriculture 60%
Texas
Other 8%
Natural 11%
Agriculture 15%
Municipal 53%
Storm sewers/runoff 13%
Oklahoma
Storm sewers/runoff 6%
Other 5%
Land disposal 7%
Resource extraction 14%
Hydrologic/ habitat modification 17%
Agriculture 51%
Virginia
Other 7%
Municipal 8%
Natural 11%
Storm sewers/runoff 18%
Silviculture 8%
Resource extraction 7%
Agriculture 41%

Table 19.4—Leading sources of impairment of rivers and streams in Southern States from 1988 to 1998

Source of impairment[a]	AL	AR	FL	GA	KY	LA	MS	NC	OK	SC	TN	TX	VA
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - -	*Annual average*	*impaired miles[b c]*	- - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Point sources													
Municipal	642	318	575	468	1,149	3,335	1,076	296	0	974	1,994	1,522	211
Storm sewers/runoff[d]	260	40	1,775	1,162	599	1,880	605	898	513	1,251	1,995	375	472
Industrial	321	184	476	99	217	2,432	952	496	14	804	1,023	123	143
Land disposal[d]	69	27	1,364	1	731	1,847	272	260	515	105	270	78	40
Total	1,292	569	4,190	1,730	2,696	9,494	2,905	1,950	1,042	3,133	5,282	2,099	866
Nonpoint sources													
Agriculture	969	2,662	2,033	16	1,447	3,816	19,408	4,647	4,000	1,540	4,874	428	1,106
Hydrologic/habitat modification	288	14	1,244	33	186	2,022	488	279	1,339	98	3,640	27	27
Resource extraction	459	248	688	5	1,107	1,875	419	114	1,126	22	1,269	0	177
Construction	123	26	1,372	0	37	691	49	572	179	96	1,178	0	0
Silviculture	138	154	563	1	78	984	1,216	206	120	193	188	0	209
Natural	70	0	0	271	2	691	994	0	62	172	376	331	281
Total	2,047	3,103	5,901	326	2,857	10,078	22,574	5,818	6,826	2,122	11,524	785	1,800

[a] Table does not include all sources of impairment for all years, only major sources; impaired miles can be affected by multiple sources.
[b] An impaired river mile is a river mile that is classified as partially supporting overall use or not supporting overall use.
[c] Annual average impaired miles from 1988 to 1998 is defined as the total of impaired miles for each source for the years that data was reported divided by the number of years for which data was reported; for example, in Alabama, municipal sources contributed annually, on average, to the impairment of 642 river miles from 1988 to 1998.
[d] Storm sewers/runoff and land disposal include both point and nonpoint sources.
Source: U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b.

reports are discussed more thoroughly in the following section.

National Water Quality Inventories: limitations of the National 305(b) Reports—The National 305(b) Reports provide snapshots of water quality, as assessed by individual States. The reports are not recommended for determining statistically significant trends concerning our Nation's water resources (U.S. Environmental Protection Agency 1992). Some other limitations on use of these reports that have been identified include:

- Inconsistent data reporting over time (Society of American Foresters 2000).
- Variability among States regarding the compilation of reports (Society of American Foresters 2000, U.S. Environmental Protection Agency 1994).
- Insufficient water-quality data to make accurate designations in assessed waters (Society of American Foresters 2000).
- Conditions in assessed waters cannot always be extrapolated to estimate conditions in nonassessed waters; information provided by States generally reflects monitoring and evaluation efforts that have been focused within problem areas of individual waters (U.S. Environmental Protection Agency 1994).
- In some instances in the past, impaired waters were overestimated by States to qualify for greater Federal funding to address potential impairment problems, as opposed to actual impairments (Society of American Foresters 2000).

Based on these limitations, reliance on data from these reports for statistical numeric trends over time or for specific comparisons between States is not recommended. However, despite these limitations, this information represents the most comprehensive set of current water-quality data available for the South. These reports were used in this chapter to identify general trends over time and the major causes and sources of impairment to rivers and streams in the South. For each individual State, the most significant information from figure 19.3 and table 19.4 is the relative contribution of each source.

Index of watershed indicators (IWI)—The USEPA introduced the IWI program in October 1997 to increase public awareness about the health of the Nation's watersheds. The primary objectives of the IWI program are to:

- Develop a consistent, descriptive technique for characterizing the condition and vulnerability of individual watersheds across the Nation.
- Make this information available in a way that informs and inspires Americans to learn more about their water resources, what affects those resources, and how to protect and restore them.
- Help water-quality management professionals make better decisions on strategies and priorities for environmental programs.
- Establish a national baseline on the condition and vulnerability of aquatic resources that could be used over time to help measure progress toward the goal that all watersheds be healthy and productive.

In order to achieve these objectives, 15 individual indicators of condition and vulnerability of aquatic systems in each of the 2,262 watersheds in the 50

States and Puerto Rico were developed and used to rank each watershed (U.S. Environmental Protection Agency 2001e). These 15 indicators are listed and discussed in "The Index of Watershed Indicators" (U.S. Environmental Protection Agency 1997). Watersheds are delineated using the USGS eight-digit HUC classification system, as described in the preceding section "Spatial Data." Federal and State agencies, stakeholders, and other organizations contribute to the information gathered for the IWI. After making an assessment of condition, vulnerability, and data sufficiency, the condition of the watershed is scored and assigned one of the following general categories: (1) better water quality, (2) water quality with less serious problems, (3) water quality with more serious problems, and (4) insufficient data (U.S. Environmental Protection Agency 2001e).

The most recent IWI information (September 1999) was compiled to provide a current characterization of water quality in individual watersheds in the South. Figure 19.4 provides a graphic representation of this information. Table 19.5 summarizes this information at the State level. Based on these data, 188 individual watersheds (USGS eight-digit HUCS) are characterized as having relatively good water quality; these represent 30 percent of the land area in the South. Two hundred forty-one individual watersheds (36 percent of the land area) are characterized as having moderate water-quality problems, and 115 individual watersheds (15 percent of the land area) are classified as having more serious water-quality problems. One hundred twenty-eight individual watersheds (19 percent of the land area) do not have enough information to provide an overall characterization (fig. 19.4).

The majority of more serious water-quality problems are located in Louisiana, Mississippi, South Carolina, and Oklahoma. Watersheds characterized by less serious water-quality problems are scattered throughout the region, with concentrations in Georgia, South Carolina, and southern Florida. States with higher percentages of better water quality include Virginia, North Carolina, Alabama, and Arkansas. Significant areas of Texas, particularly watersheds in the western portion of the State, do not have enough information to provide an adequate characterization of water quality (table 19.5).

Table 19.6 presents the same information as table 19.5, except the IWI information is aggregated by ecological province. A complete description of the ecological provinces in the South is included in chapter 16. The best water quality is generally found in the Central Appalachian Broadleaf Forest and the Ozark Broadleaf Forest. Ecological provinces with more serious water-quality problems include the Lower Mississippi Riverine Forest and the Outer Coastal Plain Mixed Forest.

Through the "Surf Your Watershed" Internet feature on the USEPA Web page (U.S. Environmental Protection Agency 2001d), the public can access information about a watershed of interest, as well as view the IWI data for that watershed. IWI represents a focused, long-term reporting tool that may assist in pinpointing specific problems in a watershed, and in providing improved assessment of current watershed conditions and

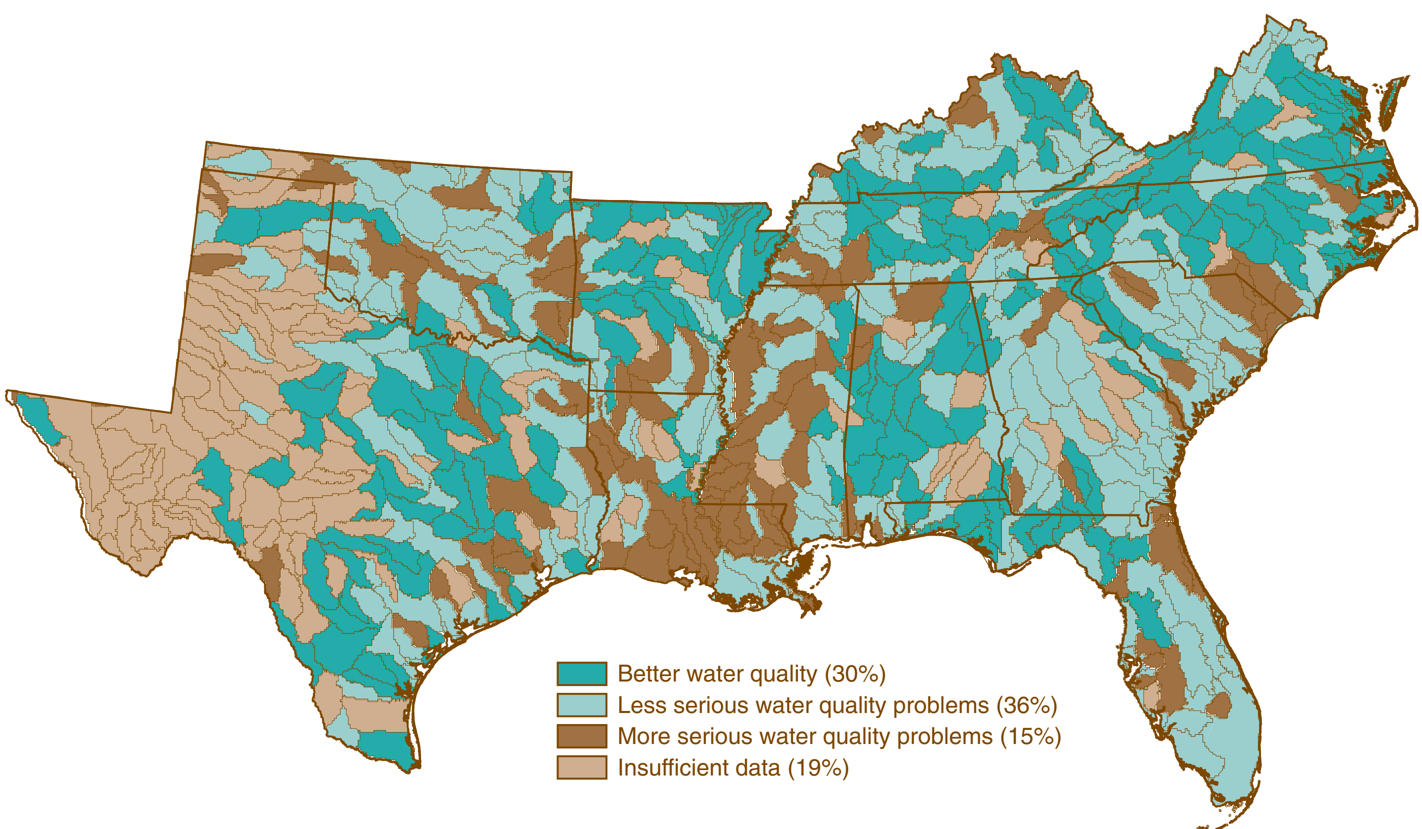


Figure 19.4—Overall characterization of water quality in southern watersheds [index of watershed indicators data (U.S. Environmental Protection Agency 1999)].

Table 19.5—Overall watershed characterization in Southern States using Index of Watershed Indicators data

State	Total watersheds		Better water quality	Less serious water quality	More serious water quality	Insufficient data
	No.	*Acres*	*Number of watersheds (percent of acres)*			
Alabama	53	(33,090,082)	22 (50.54)	19 (25.12)	5 (10.00)	7 (14.34)
Arkansas	59	(33,924,530)	27 (50.98)	20 (28.70)	7 (10.38)	5 (9.94)
Florida	54	(35,401,487)	16 (24.76)	16 (57.70)	9 (16.24)	4 (1.30)
Georgia	53	(37,512,562)	16 (14.98)	28 (66.47)	4 (6.52)	5 (12.03)
Kentucky	47	(25,747,680)	15 (36.57)	23 (53.11)	8 (9.94)	1 (0.34)
Louisiana	58	(29,554,483)	5 (5.07)	19 (35.25)	29 (50.79)	5 (8.89)
Mississippi	56	(30,461,735)	8 (8.37)	20 (42.15)	25 (45.11)	3 (4.37)
North Carolina	57	(31,387,170)	32 (59.76)	16 (26.86)	6 (9.75)	3 (3.63)
Oklahoma	70	(44,743,486)	8 (11.64)	37 (58.40)	17 (24.47)	8 (5.49)
South Carolina	36	(19,759,604)	8 (13.09)	18 (62.07)	9 (24.81)	1 (.02)
Tennessee	62	(26,992,715)	29 (43.91)	20 (33.16)	8 (15.98)	5 (6.96)
Texas	206	(168,984,378)	48 (28.64)	47 (19.15)	22 (7.05)	89 (45.15)
Virginia	54	(25,615,321)	26 (59.92)	23 (33.76)	0 (0)	5 (6.32)

Source: U.S. Environmental Protection Agency 1997, 1999.

future trends (U.S. Environmental Protection Agency 2001e).

Other water-quality assessment programs: NAWQA program—USGS established the NAWQA program in 1991 to assess and provide past, present, and future water-quality conditions in 60 river basins and aquifers nationwide. The NAWQA program is a long-term comparative study of the relationship between human impact and natural factors and the resulting water-quality condition within an area. NAWQA studies focus on region-specific factors that affect aquatic habitat.

The assessed areas, referred to as study units, account for 60 to 70 percent of the Nation's water use, and cover about one-half of the land area of the United States (U.S. Geological Survey 2001b). Assessments were initiated in 20 study units in 1991, 20 in 1993, and 20 in 1997, and data were collected by Federal, State, and local agencies, as well as universities and environmental groups. The 16 NAWQA study units for the South are presented in table 19.7. Due to the number of individual basin reports, specific findings for each study unit are not summarized in this report; however, some key findings from several of the basin studies are discussed in individual sections following as they relate to the effects of various land uses on water quality. Additional information on each of the southern study units, including specific reports and key study findings, can be accessed via the USGS Internet site at http://water.usgs.gov/nawqa/nawqamap.html.

Other water-quality assessment programs: Southern Appalachian assessment—A recent study conducted in the Southern Appalachians indicates that overall water quality has improved slightly since passage of the CWA (Southern Appalachian Man and the Biosphere 1996). The Southern Appalachians include an area of approximately 37.4 million acres of mountains, foothills, and valleys stretching from northern Virginia and eastern West Virginia to northwestern South Carolina, northern Georgia, and northern Alabama. Other key findings included in this study were:

- Population growth and landscape alterations have resulted in water-quality degradation.
- The Tennessee River and Alabama River Basins are the most significantly impacted watersheds in the Southern Appalachians.
- Acidity of some streams in the area is increasing.
- Mining, urbanization, and dams have the largest effects on regional hydrology.
- Two-thirds of the reported localized water-quality impacts were a result of nonpoint-source pollution, including agricultural runoff, stormwater discharge, and landfill and mining leachate.
- Mining impacts on water quality occur in the Tennessee River Basin and southwestern Virginia.

Land Use Impacts on Water Quality

Role of forests in protecting water quality—According to Sedell and others (2000), 80 percent of the freshwater resources in the United States originate in forests. Therefore, having healthy forests is critical to having clean water. The quality of water draining from forested watersheds is typically the highest in the country (Binkley and Brown 1993, Clark and others 2000). Undisturbed forests or woodlands generally provide the best protection of land and water from sedimentation and other pollutants. The tree canopy and litter layer dissipate the energy contained in raindrops. Also, a continuous litter layer maintains a porous soil surface and high water infiltration rates; consequently, overland flow is minimized in the forest. Forests slow stormwater runoff and provide watershed stability and critical habitat for fish and wildlife (Sedell and others 2000).

The body of literature that examines the role of forests, as compared to other land uses, in protecting water quality is significant. This section summarizes some of the key findings from various studies throughout the Nation and the South related to sediment yield,

Table 19.6—Watershed characterization of ecological provinces in the South using Index of Watershed Indicators data

Ecological Province[a]	Total watersheds		Better water quality		Less serious water quality		More serious water quality		Insufficient data	
	No.	*Acres*	*- - - - - - - - - - Number of watersheds (percent of acres) - - - - - - - - - -*							
E. Broadleaf (Oceanic) (221)	41	(12,011,675)	17	(40.43)	17	(42.78)	2	(9.02)	5	(7.77)
Central Appalachian (M221)	52	(20,960,016)	23	(55.19)	23	(39.37)	4	(1.52)	2	(3.92)
E. Broadleaf (Contl.) (222)	76	(41,470,850)	29	(42.33)	30	(41.86)	14	(12.79)	3	(3.01)
Ozark Broadleaf (M222)	15	(4,136,528)	8	(52.34)	4	(22.38)	2	(14.39)	1	(10.89)
Southeastern Mixed (231)	199	(112,330,643)	65	(35.11)	73	(39.22)	43	(17.56)	18	(8.12)
Ouachita Mixed (M231)	18	(7,153,279)	8	(38.65)	5	(24.37)	4	(30.98)	1	(6.00)
Outer Coastal Plain (232)	216	(126,888,978)	54	(24.02)	93	(45.90)	48	(21.51)	21	(8.57)
Lower Miss. Riverine (234)	87	(27,494,018)	17	(27.39)	31	(36.60)	36	(31.89)	3	(4.12)
Prairie Parkland (Temp.) (M251)	12	(2,571,329)	2	(2.29)	9	(75.21)	1	(22.50)	0	(0)
Prairie Parkland (Subtrop.) (255)	113	(55,793,413)	35	(37.52)	49	(39.69)	16	(16.18)	13	(6.61)
Everglades (411)	6	(5,253,389)	0	(0)	4	(91.07)	1	(7.18)	1	(1.75)

[a] Bailey's ecological provinces, represented by three digit codes; leading "M" indicates mountainous topography.
Source: U.S. Environmental Protection Agency 1997, 1999.

nutrient yield, and biological conditions in forested versus nonforested watersheds. A number of these reports have been completed as part of the NAWQA program described in the preceding section.

Patric and others (1984) and Yoho (1980) compiled the range of sediment yields from several small watershed studies throughout the Nation and the South, respectively. Both of these reviews concluded that forested lands produced a small fraction of the sediment yielded by more intensive land uses. Periodic timber harvesting activities occurred in many of the forested watersheds. Even with a wide diversity of forest types, geology, climate, and physiography, forested watersheds yielded far less sediment than areas where nonforest land uses occurred (Patric and others 1984). In the upper Mississippi River Basin, sediment yield increased 150-fold from the forested headwaters to downstream areas dominated by other land uses, including agriculture (Mack 1967). Runoff and annual sediment yields were greatest from agricultural lands compared to pine plantations and mature pine-hardwoods in small watersheds in northern Mississippi (Ursic and Dendy 1963).

Faye and others (1980) compared erosion and suspended sediment yields in nine watersheds in the upper Chattahoochee River Basin, GA, and reported the greatest suspended sediment yields from urban areas, compared with forested and agricultural lands. In a land use study in Virginia, Jones and Holmes (1985) compared the effects of urban, agricultural, and forested land uses (silvicultural activities) on water resources. They concluded that forestry practices contributed little sediment; agriculture was an important source, and urban development contributed the most sediment (as well as other pollutants).

In a nationwide review of watershed characteristics and stream nutrient levels, Omernik (1977) found that streams draining agricultural watersheds had, on average, considerably higher nutrient concentrations than those draining forested watersheds. Nutrient concentrations were generally proportional to the percent of land in agriculture and inversely proportional to the percent of land in forest (Omernik 1977).

Spruill and others (1998) conducted a water-quality assessment of the four river basins in the Albemarle-Pamlico Drainage Basin—the Chowan, Roanoke, Tar, and Neuse. Highest nitrogen and phosphorous yields occurred in the highly agricultural and urbanized Neuse Basin, and lowest nutrient yields occurred in streams of the forested Chowan Basin. In a study of the upper Tennessee River, Hampson and others (2000) found that sampling stations in forested watersheds had the lowest concentrations of total nitrogen, whereas stations in agricultural areas had the highest. Concentrations of nitrogen in urban and mixed land use areas were significantly greater than in forested watersheds but were some-

Table 19.7—National Water Quality Assessment Program study units in the South

Study year	Study unit	States
1991	Potomac River Basin	Virginia
1991	Albemarle-Pamlico Drainage	North Carolina, Virginia
1991	Apalachicola-Chattahoochee-Flint River Basin	Alabama, Florida, Georgia
1991	Georgia-Florida Coastal Plain	Georgia, Florida
1991	Ozark Plateaus	Arkansas, Oklahoma
1991	Trinity River Basin	Texas
1991	Rio Grande Valley	Texas
1994	South Central Texas	Texas
1994	Mississippi Embayment	Arkansas, Kentucky, Louisiana, Mississippi, Tennessee
1994	Southern Florida	Florida
1994	Kanawha-New River Basin	Virginia, North Carolina
1994	Upper Tennessee River Basin	Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia
1994	Santee Basin and coastal drainages	South Carolina, North Carolina
1997	Lower Tennessee River Basin	Tennessee, Alabama, Georgia
1997	Acadian-Pontchartrain	Louisiana, Mississippi
1997	Mobile River and tributaries	Mississippi, Alabama, Georgia

Source: U.S. Geological Survey 2001b.

what less than nitrogen concentrations in agricultural watersheds. As with total nitrogen, the lowest phosphorous concentrations were detected at sites in predominantly forested watersheds, whereas sites in urban and agricultural areas had the highest phosphorous concentrations (Hampson and others 2000).

In an assessment of biological indicators of the Apalachicola-Chattahoochee-Flint (ACF) River Basin, streams with forested land use had the best biological condition as shown by the Index of Biotic Integrity (Frick and others 1998). Lenat and Crawford (1994) conducted a study on the effects of land use on aquatic biota in three small catchment basins (forested, agricultural, and urban) in the Piedmont of North Carolina. Biological measurements showed large and consistent between-stream differences in the different watersheds. Invertebrate taxa richness criteria and biotic index criteria indicated good water quality, fair water quality, and poor water-quality classifications in the forested, agricultural, and urban catchments, respectively (Lenat and Crawford 1994). For the purposes of this report, a Geographic Information System (GIS) analysis was conducted to determine if a positive relationship could be demonstrated between water quality and forest cover for watersheds. The three general IWI categories, “better water quality,” “less serious water-quality problems,” and “more serious water-quality problems,” were compared with percent forest cover for each of the southern watersheds. Percent forest cover was derived from the USDA Forest Service FIA data for each State and aggregated by watershed. However, because of the scale of the analysis (size of the watersheds) and other limitations in the use of the water-quality data at this scale, regional trends relating forest cover and water quality were not identified.

In addition, water-quality impairment based on IWI classification accounts for multiple factors and conditions that may have a greater impact on water quality than forest cover alone. Recent studies have concluded that the effects of human actions on nutrient loads may be disproportionately greater than the actual amount of anthropogenic cover in a watershed. Hession and others (1996) found that 80 percent of lake phosphorous load was attributable to agriculture, which accounted for only 25 percent of the watershed area. Nutrient export from agriculture was determined to be disproportionately greater than its area within a watershed. Although urban and suburban land use accounts for only 5 percent of the ACF River Basin, it has the most significant effect on streamwater quality (Frick and others 1998).

The scale of any watershed analysis is critical to determining specific relationships between land uses and water quality. Effects of land uses, including silvicultural practices, on water quality and aquatic biota are best studied and summarized at much smaller scales. This level of analysis was not possible for this report.

Specific land uses affecting water quality in the South—Based on a nationwide study of streams draining forested land, Patric and others (1984) concluded that land use has more influence on average sediment concentration in watersheds than does any other single factor. Land uses (practices) that are major sources of water-quality impairment in the South, and the pollutants that they may generate, are discussed in this section. Figure 19.1 displays the leading point and nonpoint sources of pollution from 1988 to 1998. Figure 19.3 displays this information by State. Primary land use practices (or types) affecting water-quality impairment in the South can be grouped into five broad categories: (1) agriculture, (2) urbanization, (3) resource extraction, (4) hydrologic/habitat modification, and (5) silviculture. At the local and regional level, land use practices can dramatically affect soil condition and water quality, as well as water supply. Factors that affect land use change include economic growth, population density, social development, political structure, attitudes and values, and technology (Turner and others 1993). Five major land use categories are discussed in the subsections that follow.

■ *Agriculture*: From 1988 to 1998, agriculture was identified as the primary source of water-quality impairment in the South. It accounted for a majority of the pollution impacting rivers and streams in the South (fig. 19.1). An annual average of approximately 44,326 miles of rivers and streams was impacted by agricultural activities during this period. Until the 1950s, the growth of agricultural land use generally kept pace with population increases (Novotny and Olem 1994). The majority of farming was conducted on small family farms without excessive use of chemicals. Since then, farming has shifted from family farms to larger corporate enterprises. Concurrently, farming began to rely on chemical fertilizers to increase plant yields, and on pesticides for insect and weed control. In general, as environmental awareness has increased, modern day agricultural practices have begun to incorporate techniques that reduce potential environmental impacts.

Despite these advances, agricultural practices continue to be the primary source of water-quality impairment in the South (U.S. Environmental Protection Agency 2000b). For example, in North Carolina construction activities typically cause the highest erosion rates, but agriculture is the most common source of sediment problems because of the large amount of agricultural land use (Lenat and Crawford 1994). Agricultural activities such as field tillage, pesticide and fertilizer applications, drainage, irrigation, grazing, and feedlot operations are sources of significant nonpoint-source pollution (Neary and others 1989). Major pollutants associated with agriculture include sedimentation; nitrogen and phosphorous loading; changes in soil salinity; and introduction of pesticides, other toxins, bacteria, and pathogens. Agricultural practices are more likely to contribute certain pollutants than other land use practices. Agricultural land cover is considered one of the principal sources of excess loads of nitrogen and phosphorous in receiving waters (Parry 1998).

Concentrated animal operations (CAOs) are a major agricultural practice that contributes significant amounts of pollutants to rivers and estuaries in the South (Burkholder and others 1997, Mallin 2000). For example, North Carolina experienced a rapid increase in CAOs between 1980 and 1990. The CAOs were exempt from land zoning laws and mandatory inspection programs. The waste lagoons were not required to have impermeable liners, and some were even constructed below the water table (Burkholder and others 1997). During heavy rainfall events, the waste lagoons overflowed, resulting in an increase in biochemical oxygen demand, fecal coliform, and nutrients and a decrease in dissolved oxygen, possibly resulting in fish kills (Burkholder and others 1997). Typical agricultural practices and associated pollutants are summarized in table 19.8 (Novotny and Olem 1994).

■ *Urbanization*: Urbanization is defined as land use conversion caused by increased population density and activities associated with the creation of infrastructure to support populations, primarily within cities. Features of urbanization addressed in this chapter include construction of homes and other buildings, infrastructure development such as municipal wastewater treatment plants and storm sewer systems, construction of industrial plants, urban sprawl, and creation of extended transportation routes, including mass transit.

Urban areas account for a small percentage of land in the South, but their effects on water resources have been severe. Urbanization represents the second overall leading source of impairment to water quality.

Table 19.8—Agricultural land use practices and associated pollutants

Agricultural land use practices	Pollutants (causes)
Nonirrigated cropland	Sedimentation, nutrients, pesticides, streambank destabilization, removal of riparian vegetation.
Irrigated crop production	Sedimentation, nutrients, pesticides, traces of certain metals, salts, bacteria, viruses.
Rangeland	Bacteria, nutrients, sedimentation, pesticides, streambank destabilization, flow alteration, removal of riparian vegetation, increases in water temperature, reductions in dissolved oxygen concentrations.
Pasture land	Bacteria, nutrients, sedimentation, pesticides, streambank destabilization, flow alteration, removal of riparian vegetation, increases in water temperature, reductions in dissolved oxygen concentrations.
Feedlots	Bacteria, viruses, nutrients, sedimentation, organic material, salts and metals.
Animal holding areas	Bacteria, viruses, nutrients, sedimentation, organic material, salts and metals.
Animal operations	Bacteria, viruses, nutrients, sedimentation, organic material, salts and metals.

Source: U.S. Environmental Protection Agency 1998a, Novotny 1994.

Urbanization not only affects local rivers; it also contributes to water-quality impacts far downstream. According to National 305(b) Reports from 1988 to 1998, 5 of the 11 leading sources of water-quality impairment in the South were due to urbanization (fig. 19.1). These include both point and nonpoint sources of runoff in the categories of: (1) municipal (wastewater treatment plants), (2) storm sewer/urban runoff, (3) industrial discharges, (4) land disposal (landfills), and (5) construction activities. These five sources impacted an annual average of approximately 37,083 miles of rivers and streams during this time.

In the first half of the 20th century, deterioration of water quality due to urbanization was primarily associated with point sources from industrial and commercial operations and treated and untreated domestic sewage. Point sources continue to contribute to water-quality impairment. It was not until 1970 that urban nonpoint sources of pollution were also recognized as contributing a significant portion of water-quality impacts. The following point and nonpoint sources of water-quality impairment are considered to be a result of urbanization.

■ Point sources of pollution: Treated sewage discharges; industrial discharges; storm sewer outflows in urban centers, including pollutants such as car oil, detergents, and other household and commercial solvents and chemicals; spills or releases from petroleum tankers, railcars, etc; unpermitted discharges from industrial or municipal sources.

■ Nonpoint sources of pollution: Runoff (sedimentation and erosion) from construction activities; runoff from roads and road construction; sediment and contaminant transport from other impervious surfaces such as parking lots; runoff from the application of pesticides and fertilizers; runoff and leachate from landfills and septic tank systems; leaking underground storage tanks and other improperly contained hazardous material storage tanks; combined sewer overflows.

Other impacts to water quality due to urbanization include reduced flow in rivers and streams caused by increased demand for water resources, such as drinking water and extensive land use changes due to urban sprawl.

■ Hydrologic/habitat modification: Hydrologic modification is the alteration of the flow of water, which changes water depth, stream velocity, and amount of discharge. Habitat modification is the removal of riparian vegetation, streambank modification, and drainage/filling of wetlands (U.S. Environmental Protection Agency 2000b). Throughout the history of modern civilization, sources of water have been modified to exploit available resources. As popu-lations have increased, modification of nearby streams, rivers, wetland areas, and lakes has increased accordingly. Traditionally, activities such as the draining of wetlands for agricultural purposes and the development of urban centers along rivers and streams have been ncouraged and considered to be signs of progress and economic growth (Mac and others 1998).

Hydrologic/habitat modification has been one of the leading causes of water-quality impairment in the South from 1988 to 1998. These activities impacted an annual average of approximately 8,153 river miles during this time (fig. 19.1) and were the third leading source of water-quality impairment, behind agriculture and urbanization. Hydrologic/habitat modification includes the following activities (specific literature citations for water-quality impacts are included):

■ Dredging: The excavation of bottom sediment to increase water depth and subsequent disposal of dredged material (Burke and Engler 1978, U.S. Army Corp of Engineers 1989).

■ Channelization: The alteration of stream morphology for human beneficial uses, such as flood control and irrigation (Crance and Masser 1996, Mac and others 1998).

■ Damming/flow regulation: A barrier preventing and regulating the flow of water for the purpose of flood control, power generation, and water resources (Federal Interagency Restoration Working Group 1998, Mac and others 1998).

■ Drainage of wetlands and swamps: The act of removing water from wetlands by altering the land for purposes such as conversion to farmland and urban development (see chapter 20).

■ Resource extraction: Resource extraction, as reported in the National 305(b) Reports, includes mining, petroleum drilling, and runoff from mine tailing sites (U.S. Environmental Protection Agency 2000b). It was one of the top five sources of water-quality impair-ment in the South from 1988 to 1998 (fig. 19.1). The most common minerals extracted by mining are coal and metallic ores (Novotny and Olem 1994). Nonpoint sources of pollution associated with resource extraction include mineral and sediment discharges from inactive mining operations, sedimentation and erosion runoff from roads, old tailings, and spoil pile leaching of contaminants. In addition, acid mine drainage can severely impact water quality by altering pH levels of rivers and streams.

A national stream survey by the USEPA reported that 10 percent of the streams in the northern Appalachians were acidic due to acid mine drainage during spring baseflow (Mac and others 1998). Active mines are considered point sources of pollution, and a discharge permit is required for their operation. Nonpoint-pollution sources such as erosion and sedimentation are associated with almost every abandoned surface mine (Novotny and Olem 1994). Although mining is not as widespread as agriculture, water-quality impairment is often severe.

■ *Silviculture:* Silviculture is "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis" (Society of American Foresters 1994). It includes the application of scientific agricultural practices to grow trees for use as lumber or other products. The majority of forested land in the South has been subject to historical silvicultural activities of some type or extent. According to the National 305(b) Reports, silvicultural activities impacted annually an average of approximately 3,639 miles of rivers and streams in the South from 1988 to 1998 (fig. 19.1). Table 21.1 in chapter 21 provides a breakout of this information by State.

Silviculture ranks low among water-impairing land use activities in the South. Nevertheless, impacts from silvicultural activities can be consider-able if BMPs are not applied. The major potential nonpoint-source pollutant resulting from silvicultural activities is sediment from roads and skid trails.

Other minor nonpoint-source impacts on water quality include short-term increases in peak flows during storms, short-term increases in base flows, short-term increases in nutrient concentrations (primarily nitrogen and phosphorous), short-term increases in herbicides/fertilizers and derivative products, and thermal pollution (increased stream temperature). Elevated levels of organics and nutrients may result from leaching of disturbed or exposed soils. Fertilizer applications may alter stream chemistry in managed forests, depending on the type of fertilizer used and how it is applied (Society of American Foresters 2000). In comparison, pollutant loads from properly managed areas are considered negligible (Novotny and Olem 1994). Chapter 21 provides a complete discussion of the potential effects of silvicultural activities on water quality.

The Likely Future of Water Quality in the South

The population of the United States is expected to reach nearly 400 million people by the year 2050, and Texas and Florida are among the States with the fastest growing populations in the country (U.S. Census Bureau 1997). Suburbs and rural areas are expanding. As a result, the needs for recreation, timber, clean water, and other forest benefits are also increasing. Although the current trend is generally toward improved water quality in the United States, uncontrolled land use practices may alter this trend. Loss of wildlife and vegetation, erosion of soils, and nonpoint-source pollution of ground water and surface water will result in a trend of degrading water quality. According to the study "Status and Trends of the Nation's Biological Resources," "there are enough scientifically documented declines of species abundances and extinctions of aquatic species that are direct results of human activity to indicate that present water-use and development practices cannot continue" (Mac and others 1998). It should also be noted that although this chapter did not focus on estuarine and coastal resources, a number of studies indicate that due to population increases, water quality in coastal regions is likely to significantly degrade in a number of areas, including the South (Dame and others 2000, Mallin and others 2000). Understanding cumulative downstream impacts is essential to assessing the likely future of water quality, especially in these coastal regions.

The likely future of water quality in the South depends on the success of future mandates, specific programs, and initiatives to promote water-quality improvements. Some of the major programs are described in the following sections.

Clean Water Action Plan (CWAP)—In 1998, President Clinton announced a new clean water initiative to speed the restoration of the Nation's waterways. This initiative, called the Clean Water Action Plan (CWAP), aims to achieve clean water by strengthening public health protection, targeting community-based watershed protection efforts, and providing communities with new resources to control polluted runoff. The intended purpose of CWAP is a reemphasis of the original goal of the CWA, which was to achieve "fishable and swimmable water for every American" (Clean Water Action Plan 2001). The CWAP builds on existing programs and proposes new efforts that support partnerships between Federal, State, and local levels. These efforts include financial assistance and incentives to aid in the restoration of aquatic systems within watersheds. Four areas identified as imperative to the success of CWAP include: (1) a watershed approach, (2) strong Federal and State standards, (3) natural resource stewardship, and (4) informed citizens and officials.

Unified Watershed Assessment (UWA)—One of the key objectives of CWAP was to encourage States and tribes to work together with the public to identify watersheds that do not meet water quality and other natural resource goals and watersheds that are in the most critical need of restoration and protection. This objective would be accomplished through the conduct of UWAs. UWAs represent some of the first coordinated efforts to develop common priorities to restore and protect water quality. The designation of these watersheds would use common criteria within one of four categories, as described following (Clean Water Action Plan 2001).

- Watersheds in need of restoration: These watersheds do not meet clean water goals, and are considered priorities for restoration. States and tribes have developed subcategories to further prioritize watersheds in need of restoration based on the degree of vulnerability or threat to water-quality conditions. These include: (1) highest restoration priority—those watersheds determined by States to be most in need of restoration, and (2) other restoration needed—the remaining watersheds in need of restoration.
- Watersheds meeting goals, including those needing actions to sustain water quality: These watersheds meet clean water and other natural resource goals and standards and support healthy aquatic systems.
- Watersheds with pristine/sensitive aquatic system conditions on land administered by Federal, State, or tribal governments: These watersheds contain pristine water quality, other sensitive aquatic system conditions, and drinking water sources that are located on land administered by Federal, State, or tribal governments. These areas include currently designated and potential candidate wilderness areas, outstanding natural resource waters, and wild and scenic rivers.
- Watersheds with insufficient data to make an assessment: These watersheds lack significant information or the critical data elements needed to make a reasonable assessment.

Once prioritized, each State and tribe must develop restoration action strategies, a long-term schedule, and a description of the information used to base priority decisions through their UWA. States that share a watershed, such as in the ACF River Basin in Georgia, Alabama, and Florida, are encouraged to exchange information and work closely to reach common goals (Natural Resource Conservation Service 2001).

The UWA designations for individual watersheds (eight-digit HUCs) in the South were compiled to identify the specific watershed restoration and protection priorities based on certain factors such as water quality. Figure 19.5 provides a graphic representation of this information. Table 19.9 summarizes this information at the State level. The information that is presented in figure 19.5 is similar to that shown in figure 19.4 (IWI data), but UWA data focuses on restoration priorities of watersheds established by individual States.

Based on the results of the UWA characterization, 391 individual watersheds, which represent approximately 59 percent of the land area in the South, have been categorized as in need of some level of restoration. Of these, 148 watersheds (25 percent of the land area) are designated as the highest restoration priority, and 243 watersheds (34 percent of the land area) are classified as "other restoration needed." One hundred ninety-four individual watersheds (29 percent of the land area) are classified as meeting standards, and two individual watersheds (less than 1 percent of the land area) are considered very high quality. The two very high-quality watersheds are in Mississippi and North Carolina. For 85 individual watersheds (12 percent of the land area), information is insufficient for overall characterization (fig. 19.5). Georgia has the highest percentage of watershed acreage designated as having the highest restoration priority (22 individual watersheds), followed by Louisiana and Virginia (table 19.9).

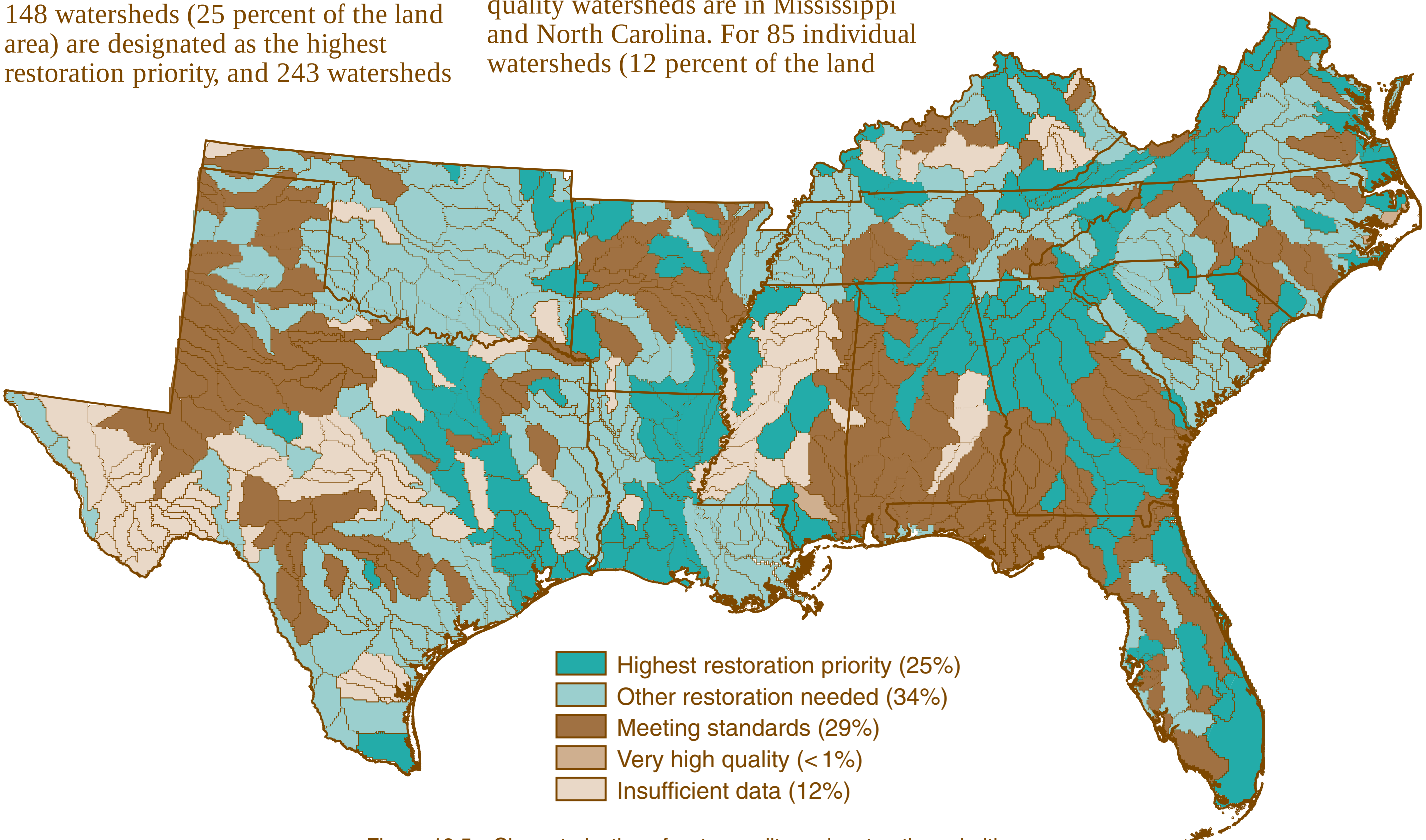


Figure 19.5—Characterization of water quality and restoration priorities of southern watersheds [unified watershed assessment data (U.S. Environmental Protection Agency 1998b)].

Table 19.9—Overall watershed characterization in Southern States using Unified Watershed Assessment criteria

State	Total watersheds		Very high quality		Meeting standards		Other restoration needed		Highest restoration priority		Insufficient data	
	No.	*Acres*	*- - - Number of watersheds (percent of acres) - - -*									
Alabama	53	(33,090,082)	0	(0)	34	(59.21)	2	(0.33)	12	(30.58)	5	(9.88)
Arkansas	59	(33,924,530)	0	(0)	20	(42.76)	22	(31.69)	13	(23.76)	4	(1.78)
Florida	54	(35,401,487)	0	(0)	35	(51.02)	7	(15.11)	12	(33.87)	0	(0)
Georgia	53	(37,512,562)	0	(0)	27	(44.69)	4	(4.43)	22	(50.88)	0	(0)
Kentucky	47	(25,747,680)	0	(0)	6	(12.61)	20	(32.60)	13	(31.72)	8	(23.07)
Louisiana	58	(29,554,483)	0	(0)	0	(0)	27	(46.70)	21	(47.77)	10	(5.54)
Mississippi	56	(30,461,735)	1	(2.72)	14	(19.92)	11	(6.27)	9	(26.57)	21	(44.51)
North Carolina	57	(31,387,170)	1	(1.29)	15	(29.80)	27	(45.73)	14	(23.18)	0	(0)
Oklahoma	70	(44,743,486)	0	(0)	9	(7.47)	48	(77.49)	9	(8.30)	4	(6.74)
South Carolina	36	(19,759,604)	0	(0)	7	(13.43)	21	(60.55)	8	(26.02)	0	(0)
Tennessee	62	(26,992,715)	0	(0)	11	(28.92)	34	(51.91)	17	(19.17)	0	(0)
Texas	206	(168,984,378)	0	(0)	58	(31.05)	76	(33.30)	26	(12.91)	46	(22.74)
Virginia	54	(25,615,321)	0	(0)	6	(14.82)	23	(39.08)	24	(46.11)	1	(0)

Source: U.S. Environmental Protection Agency 1998b.

Table 19.10—Watershed characterization of ecological provinces in the South using Unified Watershed Assessment criteria

Ecological Province[a]	Total watersheds No.	Total watersheds Acres	Very high quality	Meeting standards	Other restoration needed	Highest restoration priority	Insufficient data
	No.	*Acres*	*Number of watersheds (percent of acres)*				
E. Broadleaf (Oceanic) (221)	41	(12,011,675)	0 (0)	8 (18.11)	16 (40.13)	12 (27.45)	5 (14.31)
Central Appalachian (M221)	52	(20,960,016)	0 (0)	6 (14.08)	19 (24.69)	25 (59.82)	2 (1.41)
E. Broadleaf (Contl.) (222)	76	(41,470,850)	0 (0)	18 (22.58)	36 (37.93)	17 (30.03)	5 (9.47)
Ozark Broadleaf (M222)	15	(4,136,528)	0 (0)	5 (35.03)	6 (21.32)	4 (43.64)	0 (0)
Southeastern Mixed (231)	199	(112,330,643)	0 (0)	51 (23.23)	68 (32.47)	59 (34.40)	21 (9.89)
Ouachita Mixed (M231)	18	(7,153,279)	0 (0)	8 (25.31)	7 (45.16)	2 (20.41)	1 (9.12)
Outer Coastal Plain (232)	216	(126,888,978)	2 (0.97)	82 (42.92)	62 (24.45)	54 (25.91)	16 (5.75)
Lower Miss. Riverine (234)	87	(27,494,018)	0 (0)	10 (18.88)	39 (32.81)	21 (35.20)	17 (13.11)
Prairie Parkland (Temp.) (M251)	12	(2,571,329)	0 (0)	0 (0)	9 (82.18)	3 (17.82)	0 (0)
Prairie Parkland (Subtrop.) (255)	113	(55,793,413)	0 (0)	13 (9.05)	59 (52.49)	27 (25.80)	14 (12.66)
Everglades (411)	6	(5,253,389)	0 (0)	2 26.94)	1 (0.14)	3 (72.93)	0 (0)

[a] Bailey's ecological provinces, represented by three digit codes; leading "M" indicates mountainous topography.
Source: U.S. Environmental Protection Agency 1998b.

Table 19.10 presents the same information as table 19.9, except the UWA information is aggregated by ecological province. A complete description of the ecological provinces in the South is included in chapter 16. The ecological province with the fewest watersheds, the Everglades, has the most need for restoration. Approximately 73 percent of the Everglades Province, which consists of some 5.25 million acres, is in the most critical need of restoration. Watersheds in the Central Appalachian Province have also been targeted for significant restoration efforts. The Outer Coast Province, which is the largest ecological province in the South, contains the highest percentage of watershed acreage categorized as meeting standards or very high quality.

Total Maximum Daily Load (TMDL) program—The TMDL program is identified in Section 303(d) of the CWA. It requires States to determine the TMDLs that would be necessary to bring those waters up to water-quality minimums, and allocate those loads among sources in discharge permits and State water-quality plans. USEPA defines a TMDL as "a calculation of the maximum amount of a pollutant that a water body can receive and still meet water-quality standards, and an allocation of that amount to the pollutant's sources" (U.S. Environmental Protection Agency 2000a). Included in this amount or "pollution budget" is a margin of safety to ensure that water bodies can be used for the State-designated uses, such as swimming, recreation, and fishing.

Under the CWA, States are required to develop TMDLs for water-quality limited water body segments and promote effective nonpoint-source controls (Boyd 2000). State regulatory agencies determine the steps needed to improve or restore the quality of impaired waters through either approved TMDL implementation plans or the continuous planning process as mandated by Section 303(e) of the CWA. The development and implementation process for TMDLs is designed to promote stakeholder consensus in technical evaluation and development of management strategies for the identified water-quality problems. The establishment of TMDLs for specific watersheds or subwatersheds is the primary approach to watershed restoration efforts identified as part of the UWA process.

National Pollutant Discharge Elimination System (NPDES) stormwater program—Congress amended the CWA in 1987 to include a two-phase national program addressing stormwater discharges. Under the initial NPDES Phase 1 program, separate municipal storm sewer systems (MS4s) serving 100,000 or more people and operators of construction activities disturbing five or more acres must obtain an NPDES stormwater permit (U.S. Environmental Protection Agency 2001b). The NPDES Phase 2 program was finalized in 1999, and is scheduled for full implementation by 2003. The new requirements were established to protect water resources from stormwater runoff in regulated MS4s serving populations less than 100,000 and construction sites that disturb from 1 to 5 acres (U.S. Environmental Protection Agency 2001b).

Incentives and stewardship programs—A number of stewardship programs have been established to promote good land use practices, proactive thinking on the part of companies and private landowners with regard to multiresource management, and financial incentives for participation. Specific to forestry activities, the American Forest and Paper Association (AF&PA) recently began a stewardship initiative to incorporate the protection of natural resources. Under the Sustainable Forestry Initiative (SFI) program, water-quality improvement is specifically targeted by implementation of BMPs, approved State water-quality programs, and adherence to State and Federal water-protection laws and regulations. A similar program, the Forest Stewardship Council (FSC) certification program, was established in 1993 by environmental groups, the timber industry, foresters, indigenous peoples, and community groups from 25 countries. The FSC program is designed to promote responsible forest management by certifying forest products that meet rigorous standards. The FSC certification standards encourage environmentally appropriate, socially beneficial, and economically viable management of the World's forests.

The USDA Forest Service initiated a Forest Stewardship Program, similar to the SFI program, that provides educational and technical assistance to landowners interested in active management of their forests for multiple resource benefits. Another program, the Stewardship Incentive Program (SIP), provides cost-share support for nonindustrial private forest landowners to help them develop and implement forest stewardship plans. Funding through SIP is based on landowner adherence to the plan for a minimum of 10 years. Technical and planning assistance by natural resource professionals is available through the program.

Source Water Assessment Programs (SWAPs)—The Safe Drinking Water Act Amendments of 1996 require States to develop and implement SWAPs. These programs are intended to address existing and potential threats to public drinking water quality. Assessments will include drinking water sources and potential threats to drinking water quality for metropolitan areas, towns, schools, and restaurants. Currently, the USEPA has approved 52 SWAPs, which must be implemented by States within 3 years of USEPA approval (U.S. Environmental Protection Agency 2001c).

Fishable Waters Act—The Fishable Waters Act (FWA) of 2000 is a proposed amendment to the CWA introduced to Congress by the Clinton Administration. The objective of this act is to meet fishable and swimmable goals of the CWA . The FWA was drafted in collaboration with the Fishable Waters Coalition with the objective of restoring the physical and biological integrity of 4 million acres of public waters for fishing and recreation (Izaak Walton League of America 2001). If passed by Congress, the FWA would be a program under the CWA that would allow States to use funds in their Fisheries Habitat Account toward FWA conservation programs.

Discussion and Conclusions

Although water quality has improved since the passage of the CWA, water-quality impairment is still an important concern in the South. Several watersheds and water bodies have been identified as needing improvement and/or as being impaired for designated uses. There are too many instances of insufficient data regarding the current conditions of rivers and streams in the South. It is important to understand the difficulties in identifying causes and, in particular, sources of pollution in impaired waters. Many of the monitoring and data reporting limitations have been described in previous sections. However, USEPA and the individual States are working to develop better, more consistent methods for determining the causes and sources of impairment and describing the level of confidence in the classification.

The information included in this chapter on the status of water quality has been presented at various scales: regional, State, ecological region, and individual watershed (eight-digit HUC). The leading pollutants in rivers and streams in the South are sedimentation and pathogens (bacteria). Nonpoint-source pollution continues to degrade the overwhelming majority of rivers and streams. The primary nonpoint sources of water-quality impairment identified in the South are agriculture and urbanization. Agriculture and urbanization impact water quality by eliminating natural vegetation and replacing it with impervious surfaces or creating more readily erodible surfaces.

Therefore, preservation and restoration of forest cover are crucial to maintaining water quality in the South. Forest cover, riparian habitat, and streambank management are vital to maintaining and increasing water quality. Although the relationship is often hard to analyze statistically, loss of these habitats has had significant effects on water quality. A positive relationship between increasing forest cover and better water quality could not be identified due to problems with geographic scale and the nature of the water-quality data. In almost all instances, designation of the causes or sources of a particular water-quality impairment occurs within individual river miles. Land use, as a source of pollution, clearly plays a more significant role in degrading water quality at a local level.

Understanding land use impacts and implementation of effective management practices is the key to maintenance and improvement of water quality in the South. Sustainable land use practices are needed to maintain and improve water quality. Assessment and management issues must be addressed at regional, State, and local levels to understand the complex and interdependent relationships among natural resources and land uses. Management at the regional level is vital since impacts from land use changes are widespread and occur in different combinations and rates in different areas. As a greater understanding of cumulative downstream effects is gained, effective implementation of regional land use and watershed management programs may aid in minimizing potential water-quality impacts (Bolstad and Swank 1997).

Progress is being made to restore degraded rivers and to protect those that are still intact. The general public is becoming increasingly aware of water-quality issues. Across the South, local communities and organizations are working with State and Federal agencies to find ways to protect our rivers without adversely impacting continued economic growth. Improved public outreach and education are needed, particularly concerning nonpoint-source pollution management, wastewater operation and maintenance, and general water quality and resource management. Future trends in water quality in the South include a variety of proactive mandates, management approaches, increased awareness and implementation of BMPs, and the use of more effective and accurate technological tools.

Needs for Additional Research

As increasing land use demands affect water quality in the South, additional research and activities have been identified that would enhance the effectiveness of management programs, thereby improving water quality. The overall goal for water-quality management is to "protect our water sources, including groundwater, from contamination and overuse, and commit to maintaining or continuing to restore degraded aquatic systems, riparian forests, and natural resources" (Mac and others 1998). Recommendations and additional research needs necessary to accomplish this goal are:

- Research and develop standard assessment and reporting criteria among States for the National 305(b) Reports to Congress.
- Develop watershed assessment methods that consider costs and benefits of land use at large watershed and regional scales.
- Develop and integrate standardized tools for water-quality assessment, including modeling, use and interpretation of satellite imagery, and remote sensing.
- Develop methods to identify priority natural areas for protection and restoration as part of land management planning efforts.
- Investigate whole ecosystem impacts in restoration efforts.
- Research and incorporate downstream cumulative impacts in watershed assessment and management.
- Examine the effects historical disturbances have on current water quality.
- Investigate the long-term effects of BMPs and forest harvesting activities on sediment production.
- Research urbanization effects on forest ecosystem function and structure.

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Literature Cited

Binkley, D.; Brown, T. 1993. Management impacts on water quality of forests and rangelands. Gen. Tech. Rep. RM–239. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. [Number of pages unknown].

Bolstad, P.V.; Swank, W.T. 1997. Cumulative impacts of land use on water quality in a Southern Appalachian watershed. Journal of the American Water Resources Association. 33(3): 519–533.

Boyd, J. 2000. The new face of the Clean Water Act: a critical review of the USEPA's proposed TMDL rules. Discuss. Pap. 00–12. Washington, DC: Resources for the future. 35 p. http://www.rff.org/CFDOCS/disc_papers/PDF_files/0012.pdf. [Date accessed: March 2001].

Burk, S.A.; Engler, R.M. 1978. Water quality impacts of an aquatic dredged material disposal (laboratory investigation) synthesis report. Tech. Rep. DS–78–4. NTIS AS–A059 735. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station. 35 p.

Burkholder, J.M.; Mallin, M.; Glasgow, H.B. [and others]. 1997. Impacts to a coastal river and estuary from rupture of a large swine waste holding lagoon. Journal of Environmental Quality. 26(6): 1451–1466.

Chase, E.S. 1952. Progress in sanitary engineering in the United States. Pap. 2608. In: Pure and wholesome: a collection of papers on water and waste treatment at the turn of the century. New York: American Society of Civil Engineers: 7–17. [c1982].

Clark, G.M.; Mueller, D.K.; Mast, M.A. 2000. Nutrient concentrations and yields in undeveloped basins of the United States. Journal of the American Water Resources Association. 36(4): 849–860.

Clawson, R.G.; Lockaby, B.G.; Rummer, R.B. 1999. Harvest influences on floodwater properties in a forested floodplain. Journal of the American Water Resources Association. 36(6): 1081–1088.

Clean Water Action Plan. 2001. Restoring and protecting America's waters. http://www.cleanwater.gov. [Date accessed: March].

Cowdrey, A.E. 1996. This land, this South. Lexington, KY: University Press of Kentucky. 232 p.

Crance, J.; Masser, M. 1996. Streams: a national heritage worth preserving. ANR–911. U.S. National Biological Service, Southeastern Biological Science Center, Auburn Field Station, Auburn University. Reprinted August 1996. http://www.aces.edu/department/extcomm/publications/anr/ANR-911/anr911main.html. [Date accessed: March 2001].

Dame, R.; Alber, M.; Allen, D. [and others]. 2000. Estuaries of the South Atlantic coast of North America: their geographical signatures. Estuaries. 23(6): 793–819.

ECOMAP. 1993. National hierarchical framework of ecological units. Washington, DC: U.S. Department of Agriculture, Forest Service. 20 p.

Faye, R.E.; Carey, W.P.; Stamer, J.K.; Kleckner, R.L. 1980. Erosion, sediment discharge, and channel morphology in the upper Chattahoochee River Basin, Georgia. U.S. Geol. Surv. Prof. Pap. 1107. Washington, DC: [Publisher unknown]. [Number of pages unknown].

Federal Interagency Stream Restoration Working Group. 1998. Stream corridor restoration: principles, processes, and practices. GPO 0120–A, SupDocs A57.6/2:EN 3/PT.653. [Washington, DC]: [Government Printing Office]. [Number of pages unknown]. [ISBN–0–934213–59–3].

Frick, E.A.; Hippe, D.J.; Buell, G.R. [and others]. 1998. Water quality in the Appalachicola-Chattahoochee-Flint River Basin, 1992–1995. U.S. Geol. Surv. Circ. 1164. Washington, DC: [Publisher unknown]. 38 p.

Hampson, P.S.; Treece, M.W., Jr.; Johnson, G.C. [and others]. 2000. Water quality in the upper Tennessee River Basin, Tennessee, North Carolina, Virginia, and Georgia, 1994–1998. U.S. Geol. Surv. Circ. 1205. Washington, DC: [Publisher unknown]. 32 p.

Hansen, M.H.; Frieswyk, T.; Glover, J.; Kelly, J. 1992 The Eastwide forest inventory database: users manual. Gen. Tech. Rep. NC–151. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 48 p.

Hession, W.C.; Storm, D.E.; Haan, C.T. [and others]. 1996. A watershed-level ecological risk assessment methodology. Water Resources Bulletin. 32(5): 1039–1054.

Izaak Walton League of America. 2001. Conservation issue update. Fishable Waters Act. http://www.iwla.org/conserv/CIU/fwa.html. [Date accessed: March].

Jones, R.C.; Holmes, B.H. 1985. Effects of land use practices on water resources in Virginia. Bull. 144. Blacksburg, VA: Virginia Polytechnic Institute and State University, Water Resources Research Center. [Number of pages unknown].

Lenat, D.R.; Crawford, J.K. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia. 294: 185–199.

Mac, M.J.; Opler, P.A.; Puckett Haeker, C.E.; Doran, P.D. 1998. Status and trends of the Nation's biological resources. Reston, VA: U.S. Department of the Interior, U.S. Geol. Surv. 964 p. 2 vols.

Mack, F.J. 1967. Sedimentation in the upper Mississippi Basin. In: Soil and America's future: Proceedings of the 22^{d} annual meeting of the Soil Conservation Society of America. Des Moines, IA: [Publisher unknown]: 95–102.

Mallin, M.A. 2000. Impacts of industrial animal production on rivers and estuaries. American Scientist. 88: 2–13.

Mallin, M.A.; Burkholder, J.M.; Cahoon, L.B.; Posey, M.H. 2000. North and South Carolina coasts. Marine Pollution Bulletin. 41(1): 56–75.

McCleese, W. 1992. National hydrology workshop: watersheds in the nineties. In: Proceedings of the 1992 national hydrology workshop. Gen. Tech. Rep. RM–GTR–279. Fort Collins: CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 p.

Megahan, W.F.; Hornbeck, J. 2000. Lessons learned in watershed management: a retrospective view. In: Land stewardship in the 21^{st} century: the contributions of watershed management. RMRS–P–13. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 177–188.

Meyer, W.B. 1995. Past and present land use and cover in the U.S.A. Consequences: the nature and implications of environmental change. http://www.gcrio.org/consequences/spring95/Land.html. [Date accessed: March 2001].

Natural Resources Conservation Service. 2001. Clean water—the road ahead. http://www.nhq.nrcs.usda.gov/cleanwater/action/overview.html. [Date accessed: March].

Neary, D.; Swank, W.; Riekerk, H. 1989. An overview of nonpoint source pollution in the Southern United States. In: Hook, D.D.; Lea, R., eds. Proceedings of the symposium: the forested wetlands of the Southern United States. Gen. Tech. Rep. SE–50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 1–7.

Novotny, V.; Olem, H. 1994. Water quality: prevention, identification, and management of diffuse pollution. New York: Van Nostrand Reinhold. 1,054 p.

Omernik, J.M. 1977. Nonpoint source—stream nutrient level relationships: a nationwide study. EPA–600/3–77–105. Corvallis, OR: U.S. Environmental Protection Agency. 151 p.

Parry, R. 1998. Agricultural phosphorous and water quality: a U.S. Environmental Protection Agency perspective. Journal of Environmental Quality. 27: 258–261.

Patric, J.H.; Evans, J.O.; Helvey, J.D. 1984. Summary of sediment yield data from forested land in the United States. Journal of Forestry. 82: 101–104.

Sedell, J.; Sharpe, M.; Dravnieks, D. [and others]. 2000. Water and the Forest Service. FS–660. Washington, DC: U.S. Department of Agriculture, Forest Service. 26 p.

Sedjo, R.A. 1991. Forest resources: resilient and serviceable. In: Frederick, K.D.; Sedjo, R.A., eds. America's renewable resources: historical trends and current challenges. Washington, DC: Resources for the Future: 81–117.

Smith, R.A.; Alexander, R.B.; Wolman, M.G. 1987. Water quality trends in the Nation's rivers. Science, New Series. 235(4796): 1607–1615.

Society of American Foresters. 1994. Silviculture terminology. [Not paged]. http://www.snr.missouri.edu/silviculture/silviculture_terminology.htm. [Date accessed: March 2001].

Society of American Foresters. 2000. A review of waterbodies listed as impaired by silvicultural operations. SAF–00–03. Washington, DC: Society of American Foresters. 13 p. In cooperation with: The National Association of State Foresters.

Southern Appalachian Man and the Biosphere. 1996. The Southern Appalachian assessment aquatic technical report. Rep. 2 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 166 p.

Spruill, T.B.; Harned, D.A.; Ruhl, P.M. [and others]. 1998. Water quality in the Albemarle-Pamlico drainage basin, North Carolina and Virginia, 1992–1995. U.S. Geol. Surv. Circ.1157. Washington, DC: [Publisher unknown]. 36 p.

Trimble, S. 1974. Man-induced soil erosion on the southern Piedmont, 1700–1970. Milwaukee: University of Wisconsin-Milwaukee, Department of Geography. 162 p. In cooperation with: Soil Conservation Society of America.

Turner, B.L.; Moss, R.H.; Skole, D.L., eds. 1993. Relating land use and global land-cover change: a proposal for an IGBP–HDP core project. Report from the IGBP–HDP Working Group on land-use/land-cover change. Rep. 24. Joint publication of the International Geosphere-Biosphere Programme and the Human Dimensions of Global Environmental Change Programme. Rep. Ser. 5. Stockholm: Royal Swedish Academy of Sciences. [Number of pages unknown].

Ursic, S.J.; Dendy, F.E. 1963. Sediment yields from small watersheds under various land uses and forest covers. [In]: The second Federal interagency conference on sedimentation. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. [Number of pages unknown].

U.S. Army Corps of Engineers. 1989. Environmental effects of dredging: technical notes. EEDP–01–16. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station, Environmental Laboratory. 8 p.

U.S. Department of Agriculture, Forest Service. 2001. Plot-level data for Southern States [database]. Forest inventory and analysis datasets assembled for the Southern Forest Resource Assessment. http://www.srs.fs.fed.us/sustain/data/fia/ewplot/index.htm. [Date accessed: January].

U.S. Environmental Protection Agency. 1990. National water quality inventory: 1988 report to Congress. EPA 440–4–90–003. Washington, DC: U.S. Environmental Protection Agency. 187 p.

U.S. Environmental Protection Agency. 1992. National water quality inventory: 1990 report to Congress. EPA 503/9–92/006. Washington, DC: U.S. Environmental Protection Agency. 174 p.

U.S. Environmental Protection Agency. 1994. National water quality inventory: 1992 report to Congress. EPA 841–R–94–001. Washington, DC: U.S. Environmental Protection Agency. 328 p.

U.S. Environmental Protection Agency. 1996. National water quality inventory: 1994 report to Congress. EPA 841–R–95–005. Washington, DC: U.S. Environmental Protection Agency. 497 p.

U.S. Environmental Protection Agency. 1997. The index of watershed indicators. EPA–841–R–97–010. [Washington, DC]: [U.S. Environmental Protection Agency]. [Number of pages unknown].

U.S. Environmental Protection Agency. 1998a. National water quality inventory: 1996 report to Congress. EPA 841–R–97–008. Washington, DC: U.S. Environmental Protection Agency. 521 p.

U.S. Environmental Protection Agency. 1998b. Unified watershed assessments: clean water action plan: restoring and protecting America's waters. Individual State UWA 1998 data. http://www.epa.gov/owow/uwa. [Date accessed: January 2001].

U.S. Environmental Protection Agency. 1999. Index of watershed indicators: national maps, fact sheets, data documentation and download. Overall watershed characterization data, Sept. 1999 release. http://www.epa.gov/iwi/national/index.html. [Date accessed: January 2001].

U.S. Environmental Protection Agency. 2000a. Final TMDL rule: fulfilling the goals of the Clean Water Act [fact sheet]. EPA 841–F–00–008. Washington, DC: U.S. Environmental Protection Agency. [Not paged]. http://www.epa.gov/owow/tmdl/finalrule/factsheet1.html. [Date accessed: March 2001].

U.S. Environmental Protection Agency. 2000b. National water quality inventory: 1998 report to Congress. EPA 841–R–00–001. Washington, DC: U.S. Environmental Protection Agency. 413 p.

U.S. Environmental Protection Agency. 2001a. Clean Water Act. http://www.epa.gov/owow/cwa/history.htm. [Date accessed: March].

U.S. Environmental Protection Agency. 2001b. National pollutant discharge elimination system (NPDES) permitting program. http://www.epa.gov/npdes/. [Date accessed: March].

U.S. Environmental Protection Agency. 2001c. Source water assessment program. http://www.epa.gov/safewater/protect/swap.html. [Date accessed: March].

U.S. Environmental Protection Agency. 2001d. Surf your watershed. http://www.epa.gov/surf3. [Date accessed: March].

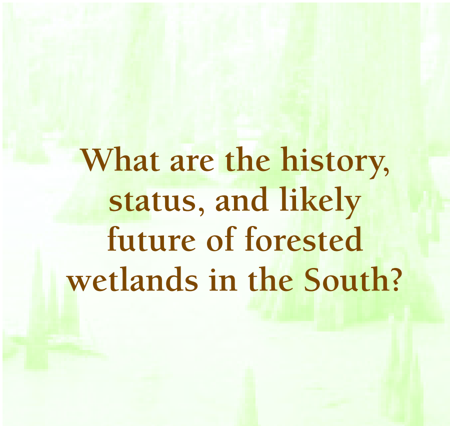
U.S. Environmental Protection Agency 2001e. Understanding the IWI. http://www.epa.gov/iwi/help/help_e.html. [Date accessed: March).

U.S. Environmental Protection Agency. 2001f. Water quality criteria and standards plan—priorities for the future. http://www.epa.gov/OST/standards/planfs.html. [Date accessed: March].

U.S. Geological Survey. 2001a. Hydrologic unit—what are hydrologic units? http://water.usgs.gov/GIS/huc.html. [Date accessed: March].

U.S. Geological Survey. 2001b. National water-quality assessment (NAWQA) program. http://water.usgs.gov/nawqa/. [Date accessed: March].

Yoho, N.S. 1980. Forest management and sediment production in the South—a review. Southern Journal of Applied Forestry. 4: 27–36.



Chapter 20: Forested Wetlands

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Key Findings

■ Approximately half of U.S. wetlands present in colonial times have been lost, primarily due to agriculture. The South had approximately 35 million acres of forested wetland remaining by 1996, 91 percent of which were riverine wetland.

■ Rates of loss—change from wetland to nonwetland—were greatest from the 1950s to the 1970s. Since then the rates have slowed, but losses are still occurring due to agriculture, urban and rural development, and silviculture.

■ According to the National Wetland Inventory (NWI), 3.5 million acres of southern forested wetland underwent changes between 1986 and 1997. Ninety percent of the changes were conversions to another wetland or aquatic habitat type. Of these conversions 95 percent were to scrub-shrub or emergent wetlands. During this same time period approximately 119,000 acres of forested wetland went into urban and rural development, 112,000 acres were converted to agriculture, and 102,000 acres underwent intensive silviculture. While NWI attributes causes of losses, they do not attribute causes of conversion.

■ Effects of harvesting are short lived, and harvested riverine stands will return to pretreatment species composition; however, additional long-term research is needed to compare composition and ecological function of harvested and non-harvested stands.

■ As of 1997, Georgia, Florida, and Louisiana have the greatest amount of forested wetland in the South, followed, in descending order, by Mississippi, South Carolina, North Carolina, Arkansas, Texas, Alabama, Virginia, Tennessee, and Kentucky.

■ Restoration has been attempted primarily in riverine wetlands in the Lower Mississippi Valley, but success in restoring wetland acreage and function has been limited. Restoration of other forested wetlands, like mineral-soil pine flats, would have to include the reintroduction of fire.

■ Offsetting losses of wetland functions through the Clean Water Act, section 404 permitting process has not been well documented but appears to have had limited success.

Introduction

This chapter describes the history, status, and likely future of forested wetlands in the South. Key issues include: (1) the quantity of forested wetlands in the South, (2) the quality of forested wetlands in the South, (3) how function is affected by impacts associated with development and agricultural and silvicultural conversions, (4) restoration of these wetland systems to replace lost functions; and (5) public policies designed to protect and restore forested wetlands. All these issues are discussed. Due to public concerns about the effects of silvicultural operations on forested wetlands and their surrounding landscapes, special attention is given to changes in condition of forested wetlands caused by silviculture.

History

Southern forested wetlands have undergone natural and human-induced disturbances for thousands of years. These disturbances have led to the species-rich flora and fauna found in these ecosystems today. Even before prehistoric humans arrived in the South, geologic changes due to plate tectonics, Appalachian Mountain uplift and subsequent erosion, rising sea levels, and the advance and retreat of glaciers resulted in ecological changes, species migrations, and shifts in community composition. Warmer climates, beginning about 16,000 years ago, caused southern forests to shift from predominantly northern softwood forests to forests dominated by oaks and hickories (Delcourt and others 1993). These climate changes and concomitant sea level rise caused many wetlands to form due to rises in water tables, which often inundated river valleys. Pre-European settlement forests were diverse, with varying tree ages interspersed with openings providing habitat for a diverse range of wildlife (Dickson 1991). Fire, ice storms, tornadoes, hurricanes, insects, and diseases disturbed these ecosystems and influenced forest composition (Askins 2001).

In addition to the long-term geologic and climatic changes and the frequent natural disturbances (primarily storms and fire), Native Americans impacted southern forested wetlands by settling and farming the fertile and tillable floodplains from the Little Tennessee River to the Mississippi River (Delcourt and others 1993). Forests were cleared not only for agriculture but also for firewood and stockades. Cleared areas were also burned regularly to prepare them for planting (Wigley and Roberts 1997). In the 16th and 17th centuries, 80 percent of Native Americans in the South died due to diseases brought by early European explorers. One result was a decline of the Native American agricultural system. Agricultural fields were abandoned, and tree growth became established on many acres of forested wetland and upland (chapter 24). Consequently, the forest vegetation encountered by southern colonists in the mid-1700s was the result of thousands of years of geologic, climatic, and human influence. Growth of forest stands that regenerated after climatic and biologic disturbances and Native American abandonment affected forest composition and age at the time of European settlement. For instance, in the Coastal Plain, abandoned agricultural fields probably supported extensive tracts of pure pine (Allen and others 1996). The forests encountered in the 1700s were not the vast, unbroken expanses of giant trees romantically portrayed early in the 19th century (Delcourt and others 1993, Wigley and Roberts 1997). Many were young stands resulting from natural and human-induced disturbances. The flora and fauna of these ecosystems were and are adapted to disturbance. In the case of mineral-soil pine flats, they require fire to maintain them. Therefore, disturbance is a natural and often forgotten component of forested wetland systems that is necessary in considering their restoration.

Definitions

What is a wetland? Current definitions include three main components: (1) the presence of water at the surface or within the root zone, (2) unique soil conditions that differ from adjacent uplands, and (3) vegetation adapted to the wet conditions (Mitsch and Gosselink 2000). Precise wetland definitions are needed by wetland managers and regulators as well as wetland scientists (Mitsch and Gosselink 2000). The wetland regulatory definition used to establish Federal jurisdiction for the wetland permitting program under section 404 of the Clean Water Act is:

> . . . those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas [33 CFR 328.3(b); 1984].

This definition of wetlands outlines the three parameters necessary for wetland development, namely hydrology, vegetation, and soils. The site-specific criteria for determining the extent to which these three parameters exist in the field is contained in the 1987 Federal Manual for Determining Wetland Boundaries (U.S. Army Corps of Engineers 1987) which is used to determine the geographic boundaries of wetlands in the United States.

The wetland definition adopted by scientists in the U.S. Fish and Wildlife Service for the purposes of inventorying wetland resources in the United States is:

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. . . . Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin and others 1979).

This definition is the standard for the NWI and is the national standard for wetland mapping, monitoring, and data reporting as determined by the Federal Geographic Data Committee (Dahl 2000).

Once a wetland-upland boundary is defined and delineated, the quality or capability of the wetland to function becomes a concern. There is great diversity in the types of wetlands in the South, the functions they perform, and the goods and services they provide society. To deal with this diversity, wetlands are grouped according to factors that substantially contribute to wetland functioning. Hydrogeomorphic (HGM) classification (Brinson 1993) groups wetlands based upon their landscape position, water source, and hydrodynamics. By grouping or classifying wetlands using the HGM classification, the presumption is that wetlands with similar landscape position, water source, and hydrodynamics will function similarly. In the Southern United States, most forested wetlands are classed as riverine, flat, and depression wetland. Much of the following discussion deals with these three classes.

Methods

The status of and trends in southern forested wetlands were derived primarily from NWI reports (Dahl 1990, 2000; Hefner and Brown 1985; Hefner and others 1994). Information from these reports was used to develop a composite picture of the acreage and loss of forested wetlands in the South from the 1780s to the present. Acreages were taken directly from the U.S. Fish and Wildlife Service Wetland Status and Trend reports for the 10 Southeastern States of Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Arkansas. Data for the 1986 to 1997 time period, generated for this report by the U.S. Fish and Wildlife Service, were also used directly. The NWI Status and Trends reports represent the most comprehensive and consistent source of information on forested wetland conversions and losses over the last 200 years.

Information from the National Resources Inventory (NRI) prepared by the Natural Resources Conservation Service (NRCS) and the Forest Inventory and Analysis (FIA) units of the USDA Forest Service were used to fill gaps in information about impact and restoration acreages and changes in forest type and ownership. NWI and NRI data have similar geographic coverage but are not directly comparable because NRI does not classify wetlands in the same manner as NWI and does not include Federal land or coastal areas in its estimates. Other differences between NWI and NRI are discussed in Dahl (2000). The FIA forested wetland data cover only five

States—Virginia, North Carolina, South Carolina, Georgia, and Florida. To date FIA has collected wetland data at only one point in time for each State. Thus, data do not represent changes in forested wetland acres over time. Since NRI and FIA data are limited geographically and temporally, NWI data are the primary basis for the status and trend numbers reported herein.

Literature, including HGM approach models for low-gradient riverine wetlands, pine flatwood wetlands, hardwood flat wetlands, and forested depressions were reviewed to develop hypotheses about the effects of alteration on the structure and function of forested wetlands. Hypothesized impacts were then checked against scientific studies done in similar wetlands where available. Predominant forested wetland types in the South (Messina and Conner 1998) were placed in HGM classes. Functional assessment models for those classes and/or subclasses were then reviewed to hypothesize, based upon structural alterations to the wetland, the impacts of alterations by silviculture, agriculture, or development. Due to the large geographic area encompassed by the Southern Forest Resource Assessment (13 States) and the large variability in onsite wetland and surrounding landscape conditions, the estimated impacts are generic. Any specific projects must be individually assessed. The generic assessments of impacts described here do provide useful insights into the ecological ramifications of these activities, the fate of wetlands which have been modified, and potential hypotheses for additional research. Wetland restoration literature was reviewed, as were ongoing studies on the extent and success of wetland restoration. NRI and data from the Wetland Reserve Program (WRP) administered by NRCS was also used to estimate the number of acres where wetland restoration has been attempted. The assumption with WRP data is that acres enrolled in this program result in a gain in forested wetland.

Data Sources

Status and trends of southern forested wetlands were derived from NWI reports for the United States and the Southeast (Dahl 1990, 2000; Hefner and Brown 1985; Hefner and others 1994). These reports also provided information on the causes of forested wetland loss. The NWI was undertaken by the U.S. Fish and Wildlife Service to provide a comprehensive inventory of the Nation's wetlands. The NWI is conducted at 10-year intervals. Gains and losses of wetlands are estimated using aerial photographs, soil surveys, topographic maps, and field work on a permanent set of randomly selected points (Dahl 2000, Shepard and others 1998). These photos are analyzed for a selected 10-year interval to detect changes in wetlands. Quality control is included throughout the data collection and analysis stages, and 21 percent of the plots are field verified (Dahl 2000). Studies have been completed for the 1950s to 1970s, 1970s to 1980s, and 1980s to 1990s.

Since NWI is used as the primary source of status and trends data for this chapter, terminology used by NWI in reporting changes in forested wetlands (Dahl 2000) is important to understand. Terms regarding wetland types and land use definitions can be found in Dahl (2000). However, two pivotal terms are defined here. "Conversion" is a change in vegetative cover on an area that is still a wetland. In other words, when a forested wetland is converted, it remains a wetland, i.e., soils and hydrology remain intact, but the dominant vegetation is changed. Wetland "loss" is a change in which an area no longer has the hydrologic characteristics of a wetland. Losses involve the detection on high-resolution aerial photographs of: (1) significant hydrologic alterations such as large ditches and levees, (2) soil alterations such as filling or leveling, and (3) upland vegetation indicating the wetland character of a site has been removed.

The NRI, prepared by the NRCS, is an inventory of multiple natural resource conditions on non-Federal land in the United States (Shepard and others 1998). The purpose of the NRI is to provide information for policymaking in natural resource conservation programs at State and Federal levels. The NRI is based upon stratified random samples distributed throughout the country. Data are collected using aerial photographs and ancillary data and by making select field visits.

FIA data gathered by the USDA Forest Service also were used in this report. The purpose of FIA is to provide information on forest resources at the local, State, and national levels. The evaluations are State-by-State multiple resource inventories of land use, timber, wildlife, range, recreation, water, and soils completed on a 7- to 10-year cycle. Data in this report were collected between 1989 and 1998 during the forest surveys in Virginia, North and South Carolina, Georgia, and Florida from field plots that met Federal wetland criteria (areas having wetland soils, plants, and hydrology) (Brown and others 2001).

Scientific literature including HGM models for low-gradient riverine wetlands (Ainslie and others 1999; Smith and Klimas 2002), pine flatwood wetlands (Rheinhardt and others 2002), hardwood flat wetlands (Smith and Klimas 2002) and forested depressions (Smith and Klimas 2002), were reviewed as a means to hypothesize the effects of conversion on the structure and function of forested wetlands. Information on land ownership and timber harvests came from FIA data and Brown and others (2001). Wetland restoration literature and university studies on the extent and success of wetland restoration also were reviewed.

Results and Discussion

Status of Forested Wetlands

In colonial times (circa 1780) the conterminous United States had approximately 221 million acres of wetlands (Dahl 1990). These wetlands had been, and would continue to be, affected by natural and anthropogenic disturbances. Over the next 200 years (circa 1980) the total wetland area in the country was reduced by over 50 percent to 104 million acres (table 20.1). Losses are primarily attributable to clearing and draining for agriculture. Frayer and others (1983) suggest that the greatest losses between the 1950s and the 1980s were in freshwater forested wetlands. Abernethy and Turner (1987) estimated losses of forested wetlands were up to five times greater than those of nonforested wetlands between 1940 and 1980. Almost 7 million forested wetland acres were lost in the Lower Mississippi Valley alone.

Table 20.1—Composite of National Wetland Inventory wetland status and trend information for the conterminous and Southeastern United States

Time period	Geographic extent of estimate	Total wetland	Forested wetland	Source
		Acres		
1780	Conterminous U.S.	221,000,000	No estimate	Dahl (1990)
1980	Conterminous U.S.	104,000,000	No estimate	
% change		47%		
1950	Southeast (10 States)	54,257,000	38,000,000	Hefner and Brown (1985)
1970	Southeast (10 States)	46,500,000	32,000,000	
% change		15%	16%	
1970	Southeast (10 States)	51,200,000	35,300,000	Hefner and others (1994)
1980	Southeast (10 States)	48,900,000	33,004,000	
% change		5%	7%	
1986	Conterminous U.S.	106,135,700	51,929,600	Dahl (2000)
1997	Conterminous U.S.	105,500,000	50,728,500	
% change		1%	3%	
1986	Southeast (10 States)[a]	49,883,779	33,735,000	
1997	Southeast (10 States)[a]	49,585,000	32,643,000	
% change		1%	3%	

[a] Estimated from percentages, specific to the South, from Hefner and others (1994) applied to national data from Dahl (2000). Wetland acreages derived from National Wetland Inventory reports and/or calculated from reported percentages.

Hefner and Brown (1985) reported that 47 percent (48.9 million acres) of the wetlands in the conterminous United States occurs in 10 Southeastern States (Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Arkansas). In addition, 65 percent of all the forested wetlands in the conterminous United States occurred in these 10 Southern States. Table 20.2 provides an estimate of total wetland acres, forested wetland acres, and forested wetland change in Southern States. Hefner and Brown (1985) reported that for the period between the 1950s and 1970s the South sustained the greatest wetland losses in the country. Forested wetland losses were attributed to massive clearing and drainage projects designed to bring wetlands into agricultural production. As of the 1970s Hefner and Brown (1985) reported that 80 percent of the 25 million acres of forested wetlands in the Lower Mississippi River Valley had been lost to agriculture. Major losses of pocosins and Carolina Bays in North Carolina were attributed to agriculture and peat mining. Overall, forested wetland acres in the South declined by 16 percent between the 1950s and 1970s (table 20.1).

Hefner and others (1994) reported that approximately 3.1 million acres (9 percent) of forested wetlands in the South were lost or converted in the 1970s and 1980s (table 20.1). Forested wetlands in these 10 Southeastern States were lost or converted at an average rate of 276,000 acres per year from the 1950s to 1970s but lost at an average rate of 345,000 acres per year from the 1970s to 1980s (Hefner and others 1994). More than 719,000 acres of forested wetlands were converted to scrub-shrub wetlands from the 1970s to 1980s. Almost 69 percent of the South's forested wetland losses were recorded in the Gulf-Atlantic Coastal Flats and Lower Mississippi Alluvial Plain (fig. 20.1). The Gulf-Atlantic Coastal Flats of North Carolina and the Lower Mississippi Alluvial Plain of Louisiana suffered the greatest losses during this time period. Nearly 1.2 million acres were lost in North Carolina, presumably to silviculture and agriculture, and nearly 1 million acres of forested riverine wetlands (bottomland hardwood wetlands) were severely affected primarily by agriculture in the Lower Mississippi Alluvial Plain. Although the net rate of wetland loss declined from 386,000 acres per year from the 1950s to 1970s to 259,000 acres per year from the 1970s to 1980s, the rate at which forested wetlands declined accelerated (Hefner and others 1994). The drop in overall wetland loss rate resumed between 1986 and 1993, declining 80 percent to 58,500 acres per year for the conterminous United States (Dahl 2000). The change in forested wetland acres during this time period was approximately 3 percent (table 20.1). Dahl (2000) estimated that nationally 4 million acres of forested wetland underwent some change in condition between 1986 and 1997. Most were converted to freshwater shrub wetlands by timber harvesting or other processes that removed the tree canopy but retained the wetland character. Table 20.1 indicates forested wetland losses exceed total wetland losses for the 1986–97 time period. This is due to the inclusion of restored wetland acreage in the "total wetland loss" category which reduces the actual losses. Table 20.3 shows a breakdown of the number of palustrine (freshwater) forested wetland acres lost or converted by activity and

Table 20.2—Comparison of total wetland and forested wetland acres and the predominant cause of change

State	Total wetland	State land surface in wetland	Forested wetland	Forested wetland change	Predominant cause of change
	Acres	*Percent*	- - - - - - - *Acres*	- - - - - - -	
Alabama	2,700,000	8	2,200,000	97,000	Agriculture
Arkansas	3,600,000	10	2,800,000	210,000	Agriculture
Florida	11,000,000	30	5,500,000	184,100	Other wetland types and urbanization
Georgia	7,700,000	20	6,100,000	500,000	Other wetland types
Kentucky	388,000	1	274,000	9,884	Agriculture and mining
Louisiana	8,800,000	28	4,900,000	628,000	Agriculture
Mississippi	4,400,000	14	3,700,000	365,000	Agriculture
North Carolina	5,000,000	15	3,400,000	1,200,000	Other
South Carolina	4,700,000	24	3,600,000	125,000	Agriculture, urban, forestry
Tennessee	632,000	2	630,000	25,000	Agriculture
Texas	6,400,000		2,500,000	60,540	Agriculture, reservoirs
Virginia			683,000	20,000	

Source: Data abstracted from Hefner and others 1994, Frayer and Hefner 1991, and Shepard and others 1998.

by State for the period of 1986–97, recorded by NWI, for the 13 Southern States included in the Southern Forest Resource Assessment. Georgia, North Carolina, Mississippi, South Carolina, and Alabama showed the greatest change in forested wetland area—over 300,000 acres per State. In each of the above cases, over 80 percent of the change in wetland type resulted from a conversion from forested wetland to shrub-scrub or emergent wetland. Overall, 90 percent of the change in forested wetland acres in the 13 Southern States resulted from these types of conversions. Ninety-five percent of the conversions of forested wetland were to shrub-scrub or emergent wetland types.

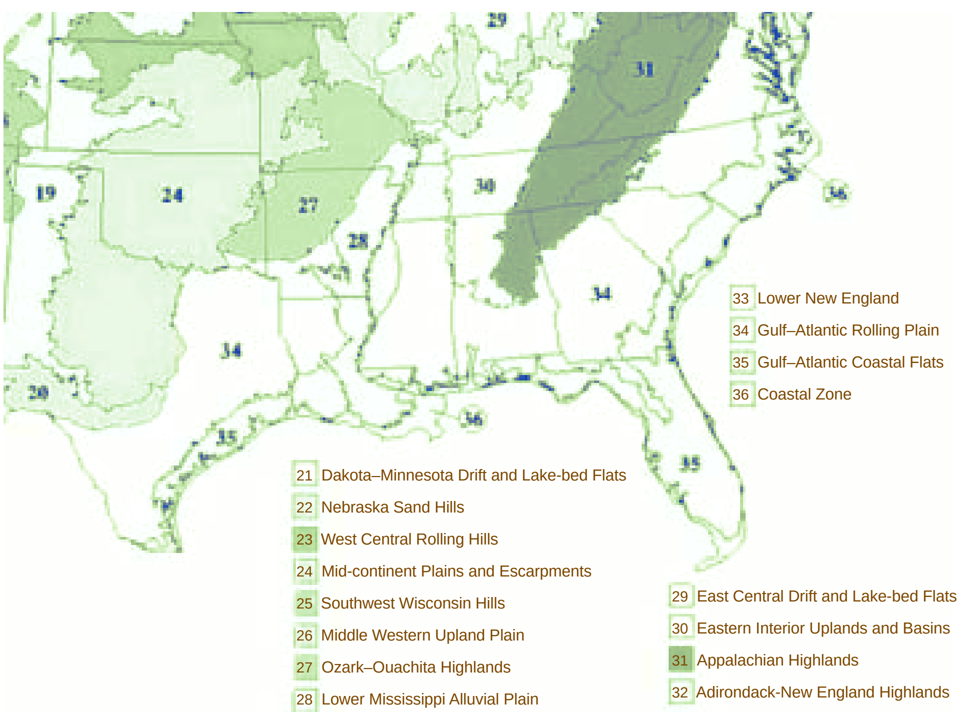

Figure 20.1—Physiographic regions of the Southern United States (Hammond 1970).

According to NWI, losses (changes from wetland to nonwetland) accounted for 10 percent of the change in forested wetlands in the South or 356,000 acres between 1986 and 1997. Thirty-three percent of the losses were due to urban/rural development, 31 percent to agriculture, and 29 percent to silviculture. The remaining 7 percent of losses of forested wetlands were attributed to other land uses. The NWI attributes losses to silviculture, if drainage occurs on any forested site (including those in agricultural or urban landscapes) such that a shift from wetland vegetation to upland vegetation is apparent (Personal communication. 2001. Charles Storrs, National Wetland Coordinator, Southeast Region, U.S. Fish and Wildlife Service, Atlanta, GA) The three States with the greatest reported losses due to silviculture were Louisiana, Georgia, and Arkansas. The three States with the greatest loss due to agriculture are Mississippi, Georgia, and Tennessee. The three States with the greatest losses to development were Florida, Mississippi, and Georgia.

Direct comparisons of various wetland inventories is difficult due to the dynamic nature of wetlands, differences in the time period in which the inventories are made, differences in geographic cover, and differences

Table 20.3—Estimated acres of palustrine forested wetland conversion and loss by State and by activity in the South[a]

State	Estimated acres of palustrine forested converted to:			Estimated acres of palustrine forested lost to:					Total estimated acres		
	Palustrine emergent	Palustrine shrub	Palustrine other	Deep-water	Agricul-ture	Urban develop	Rural develop	Silvi-culture	Other	Conversion	Loss	Change
AL	53,717	289,103	3,317		2,686	18	6,301		512	346,137 (27)	9,517 (43)	355,654 (26)
AR	25,411	100,813	13,262	5,259	1,404	149	3,619	28,958	3,213	144,745 (22)	37,343 (37)	182,088 (23)
FL	41,654	187,284	3,366	492	6,789	11,487	26,424	582	3,892	232,796 (21)	49,174 (23)	281,970 (18)
GA	108,778	677,994	18,593	2,554	24,049	12,422	7,330	30,745	6,075	807,919 (11)	80,621 (28)	888,540 (11)
KY				174	9,629				868	174 (*)	10,497 (60)	10,671 (59)
LA	21,834	83,700	25,447	13,357	9,015	1,311	4,921	40,319	4,742	144,388 (21)	60,308 (31)	204,646 (18)
MS	32,963	386,429	11,250	6,587	34,841	4,951	15,508		1,102	437,229 (29)	56,402 (45)	493,631 (26)
NC	56,393	472,116	6,235	86	2,888	1,245	2,677		246	534,830 (16)	7,056 (22)	541,886 (16)
OK	18,352	5,340	15,536	92	2,628	3,679				39,320 (42)	6,307 (69)	45,627 (38)
SC	60,368	294,246	5,298	33	1,184	9,293	3,445	630	2,185	359,945 (19)	16,737 (35)	376,682 (18)
TN		21	42		16,882	174	94			63 (*)	17,150 (64)	17,213 (64)
TX	30,357	70,262	755	118			3,040	1,005	59	101,492 (54)	4,104 (50)	105,596 (53)
VA	9,697	1,279	1,177			1,177				12,153 (64)	1,177 (*)	13,330 (59)
Total	459,524 (10)	2,568,587 (8)	104,278	28,752	111,995 (25)	45,906 (19)	73,359 (21)	102,239 (29)	22,894 (18)	3,161,141 (7)	356,393 (13)	3,517,534 (7)

Values in parentheses are percent coefficient of variation with an asterisk (*) indicating it is statistically unreliable.
[a] Estimate based on U.S. Fish and Wildlife Service, National Wetland Inventory data from 1986-97 (Dahl 2000).

in sampling and delineation protocols (Shepard and others 1998). However, indirect comparison of the NWI and NRI results are interesting. From 1982 through 1987 the NRI data indicated that urban, industrial, and residential land uses caused 48 percent of the wetland losses in the conterminous United States. Agriculture was responsible for 37 percent of wetland losses, while the remaining 15 percent were converted to barren land, open water, or forest (Brady and Flather 1994). For this time period the NRI data suggest a shift from agriculture to urban development as the major cause of wetland conversion. From 1982 to 1992 NRI data indicate that 55 percent of the total wetland loss in the Nation occurred in the 12 Southern States. During this period, wooded wetlands showed the lowest loss rate in recent decades. According to NRI, 75 percent of the losses from 1982 to 1992 were due to development (Shepard and others 1998). The updated 1997 NRI report shows that 12.5 percent of the losses of wetlands in the South are attributable to silviculture, 18.4 percent to agriculture, 58 percent to development, and 10.1 percent to miscellaneous climatic and hydrologic changes (fig. 20.2). Differences in definitions for attributing loss are a primary reason for discrepancies in wetland loss and conversion estimates between NWI and NRI (Personal communication. 2001. Charles Storrs, National Wetland Coordinator, Southeast Region, U.S. Fish and Wildlife Service, Atlanta, GA).

Land ownership patterns of forested wetlands have been summarized for 5 of the 13 Southern States by Brown and others (2001). About 60 percent of the wetland timberland in Virginia, North and South Carolina, Georgia, and Florida is privately owned. Forest industry owns 28 percent of the land, and the public owns 12 percent (Brown and others 2001). Data from the other eight Southern States is unavailable. Of the wetland timberland in the five Southern States for which data are available, 62 percent is covered with bottomland hardwoods, 25 percent with pine plantations and natural pine stands, and 10 percent oak-pine stands. Most of these forest types are in private nonindustrial ownership except for pine plantations, which are largely owned by forest industry

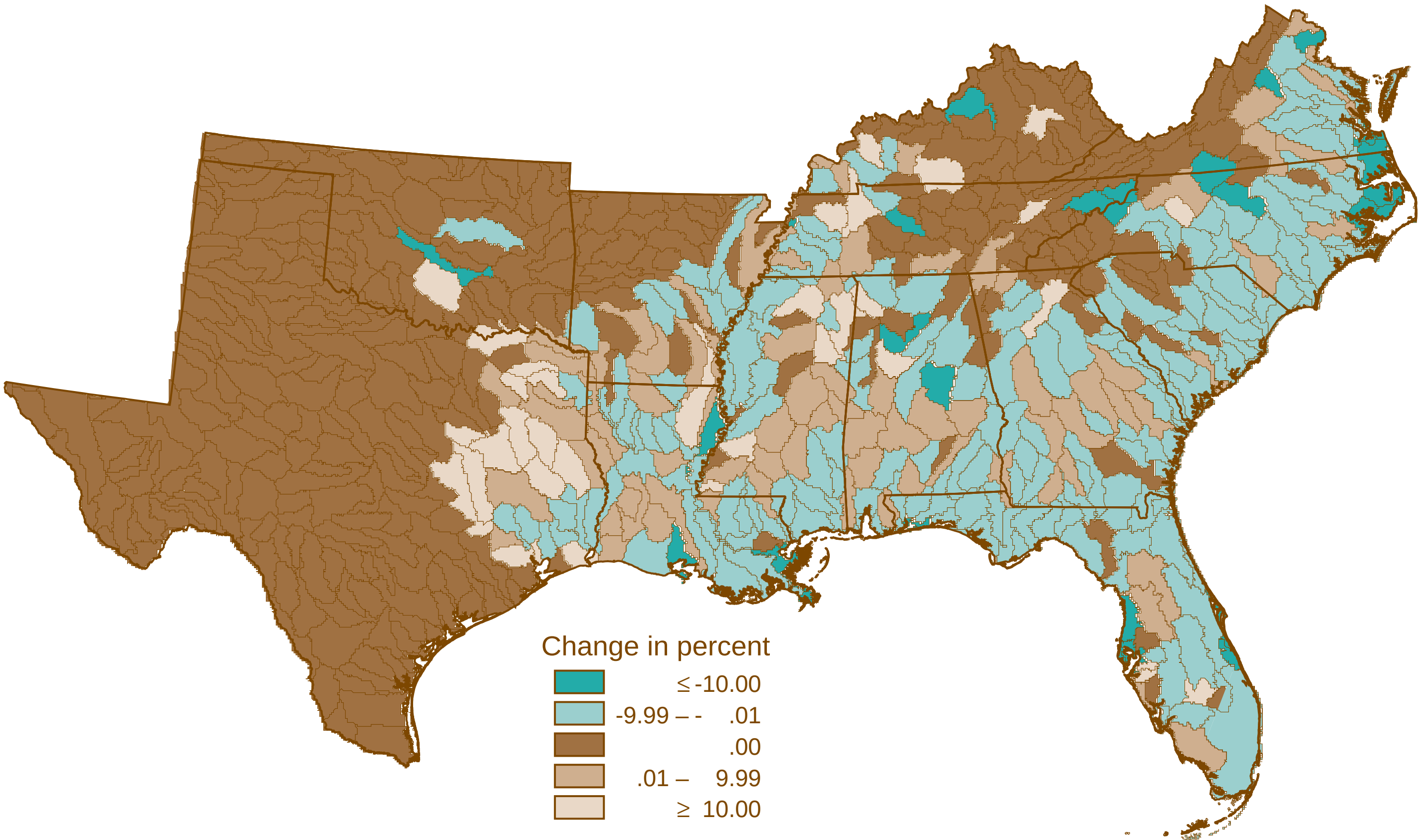

Figure 20.2—Change in forested wetlands in the South based on Natural Resources Inventory 1982 to 1987.

(68 percent) (Brown and others 2001). The percentage of timberland in wetlands and the expected increase in timber harvest in the South (chapter 13) indicate the likelihood of additional wetland modifications due to silvicultural activities.

Likely future of forested wetlands in the South—Projecting changes in forested wetlands in the South is difficult, if not impossible, because of the wide variety of scientific, societal, and economic factors that affect the forested wetland resource. Science has provided a great deal of information on how wetlands function and how human activities affect those functions. However, much information is not known and is difficult to discern. The values that people associate with forested wetlands vary greatly. They range from valuing old-growth forest to the exclusion of timber harvesting to valuing forested wetlands as merchantable timber or nothing more than potential development sites. Economic factors are important because, ultimately, wetlands are lost to development or agriculture or converted to intensive silviculture based upon economics.

This section of the chapter addresses changes in wetland condition, with particular emphasis on silviculture, current policies, and the efficacy of current forested wetland restoration efforts in the South. Additional information about forces of change in southern forests can be gained from other chapters in this Assessment.

Forested wetland types in the South are highly variable, ranging from baldcypress swamps to scrub-shrub bogs that undergo cycles of wildfire. Due to these differences in vegetation, hydrology, landscape position, and degree of alteration, wetlands differ in the functions they perform and their ability to perform those functions (Brinson and Rheinhardt 1998). Wetland functions can be simply described as the things that wetlands do. Many of these functions, such as surface and ground-water conveyance and storage, nutrient cycling, and organic carbon export provide societal benefits, goods, and services, (such as floodwater storage, water-quality enhancement, and wildlife habitat). Because of the large geographic area encompassed in this study (13 States), generalizations about forested wetlands must be made. The HGM (Brinson 1993) and functional assessment approach (Smith and others 1995) provide a means to make these broad generalizations about similar forested wetland types, the functions they perform, and the effects of certain activities on those functions.

The predominant forested wetlands in the South can be classified into four HGM classes: (1) riverine, (2) organic soil flats, (3) mineral-soil flats, and (4) depressions (Brinson 1993). Wetlands in each class occupy similar landscape positions and have similar hydrology. The presumption in HGM classification is that if wetlands occupy similar landscape positions so that the water, which drives wetland functions, comes from similar sources and flows into and out of wetlands in similar ways, the ecological processes (functions) that make wetlands important will be similar. This is a logical simplification that facilitates the discussion of wetland ecological characteristics and processes and human impacts.

In general, southern deepwater swamps, major alluvial floodplains, and minor alluvial floodplains (Messina and Connor 1998) can be combined into the riverine class. Carolina Bays, pondcypress swamps, and mountain fens can all be classified as depressions with similar depressional geomorphology and low-energy surface runoff or ground-water hydrodynamics. Wet pine flatwoods are classified as mineral-soil pine flats due to their soil composition, flat topography, and the predominance of rainfall for their hydrology. Pocosins are classified as organic soil flats. Their topography and hydrology are similar to those of mineral-soil flats, but soil composition is dominated by peat. The flats class encompasses areas dominated by pines and by hardwoods. However, mineral-soil pine flats will be the predominant flats class discussed in this chapter due to their extent, fire ecology, and vulnerability to alteration. Based upon the acreage estimates in table 20.4, riverine is the predominant HGM class in the South, followed by flatwoods and depressions.

In general, the hydrologic regime is one of the main factors controlling ecosystem functions in all wetlands and differentiating wetland types. The timing, duration, depth, and fluctuations in water level affect biogeochemical processes and plant distribution patterns. The rate, magnitude, and timing of biogeochemical processes are determined by hydrology and the living components of an ecosystem. For instance, primary producers (plants) assimilate nutrients and elements in soil and use energy from sunlight to fix carbon. When they die, they depend upon microbial organisms in soil to transform carbon and nutrients such as nitrogen and phosphorous to forms that are available to other plants. Therefore, wetland conditions that maintain plants and soil microbial populations are those that drive characteristic biogeochemical processes. These processes help to sustain the wetland plant community, which provides much of the structure required by wildlife. The integrated combination of water, soils, and plants sustains the ecosystem and provides many of the values attributed to wetlands.

Riverine wetlands—Riverine wetlands occur in floodplains and riparian corridors in association with stream channels (Brinson 1993). The dominant water source for these wetlands is from the stream channel via overbank flooding or through subsurface connections between the stream channel and the wetland. Riverine wetlands lose surface water in four ways: (1) surface flow of floodwater to the channel, (2) subsurface water flow to the channel, (3) percolation to deeper ground water, and (4) evapotranspiration. Evapotranspiration includes evaporation from soil and water surfaces and movement of water through plants to the atmosphere. Unimpacted southern forested riverine wetlands typically extend perpendicularly from a stream channel to the edge of the stream's floodplain. They have unaltered soils and a mature tree canopy, and they range from narrow riparian strips in low-order streams to broad alluvial valleys several miles wide (Sharitz and Mitsch 1993). This wetland ecosystem occurs in the Lower Mississippi River Valley as far north as southern Illinois and along many streams that drain the South Atlantic Coastal Plain into the Atlantic Ocean.

The functions of riverine wetlands are closely tied to flooding of adjacent streams and the soil and vegetation which result. Flooding is important both ecologically and societally because floodwaters move sediments and nutrients into and out of the wetlands. Wetlands detain floodwaters and prevent or minimize flood damages downstream (Kellison and others 1998, Mitsch and Gosselink 2000, Sharitz and Mitsch 1993). Riverine wetlands enhance water quality by intercepting sediments, elements, and compounds from upland or aquatic nonpoint sources of pollution. They permanently remove or temporarily immobilize nutrients, metals, and other toxic compounds (Ainslie and others 1999). Hydrologic, soil, and biological factors determine the ability of a riverine wetland to sustain a characteristic plant community. The vegetation of low-gradient alluvial riverine wetlands is extremely diverse (Sharitz and Mitsch 1993). The ability to maintain a characteristic plant community is important because of the intrinsic value of the plants themselves, and the many attributes and processes of riverine wetlands influenced by the plant community. For example, plants influence primary productivity, nutrient cycling, and the ability to provide a variety of habitats necessary to maintain local and regional diversity of animals (Brinson 1990, Gosselink and others 1990, Harris and Gosselink 1990). Riverine wetlands provide habitats for

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Table 20.4—Comparison of forested wetland community types and extents with hydrogeomorphic class

Forested community type	Predominant HGM class	Extent in the South	Source
		Acres	
Southern deepwater swamp	Riverine	[a]	Conner and Buford (1998)
Major alluvial floodplain	Riverine	11,800,000	Kellison and others (1998)
Minor alluvial floodplain	Riverine	20,000,000	Hodges (1998)
Carolina bays	Depressions		Sharitz and Gresham (1998)
Southern mountain fens	Depression/slope	6,200	Moorhead and Russell (1998)
Pondcypress swamps	Depression		Ewel (1998)
Pocosins	Organic flats	695,000	Sharitz and Gresham (1998)
Wet flatwoods (pine)	Mineral flats	2,500,000	Harms and others (1998)

HGM = hydrogeomorphic.
[a] Included in major and minor alluvial floodplain estimates.

a diversity of terrestrial, semiaquatic, and aquatic organisms. They provide access to and from uplands for completion of aquatic species' life cycles, provide refuges and habitat for birds, and act as conduits for dispersal of species to other areas. Most wildlife and fish species in riverine wetlands depend on the amount and timing of flooding, the variable topography which allows different plants and animals to become established, forest tree composition and structure, and proximity to other habitats. Riverine wetlands also must be viewed in their landscape context or in relation to the other land uses around them. Generally, the continuity of vegetation, the connection between specific vegetation types, the presence and size of corridors between upland and wetland habitats, and corridors among wetlands all have direct bearing on the movement and behavior of animals that use wetlands.

Depression wetlands—These wetlands occur in topographic depressions that allow the accumulation of surface water (Brinson 1993). Depression wetlands may have a combination of inlets and outlets or lack them completely. Potential water sources are precipitation, overland flow, streams, or ground water/interflow from adjacent uplands. Water typically flows from the outside of the depression to the center. Upward and downward movement of the water table may vary daily to seasonally. Cypress domes and Carolina Bays are typical regional forested wetland types (Messina and Conner 1998) that occur in depressions. Pondcypress domes are poorly drained to permanently wet depressional wetlands that occur in the southeastern Coastal Plain and are abundant in Florida (Ewel 1990). Cypress domes are shallow, circular, nutrient-poor swamps located in depressions on low-relief landscapes. They often have an underlying impervious layer of soil that inhibits downward movement of water. These wetlands are called "domes" because the tallest trees are in the center and the smaller trees near the edge give the appearance of a dome. Domes have long-standing, nutrient-poor water which is often dominated by precipitation and surface inflow (Mitsch and Goselink 2000). Limited plant growth rates are related to both low flow and lack of nutrient availability.

Carolina bays occur on the Atlantic Coastal Plain from New Jersey to Florida. The water source for Carolina bays ranges from predominantly precipitation to predominantly ground water. These bays occur in clusters, are commonly elliptical in shape, and are often oriented in a northwesterly to southeasterly direction. Larger, deeper Carolina bays contain lakes, but the majority of them are wetlands with diverse plant communities ranging from shrub-bog pocosins to marshes to hardwood- or cypress-dominated swamp forests. Many bays may become blanketed by an overgrowth of bog vegetation, which compresses lower layers of peat, making them relatively impervious to water movement. The result is a ponding of water, making the depression saturated for long periods of time. Bays are critical breeding sites for amphibians and habitat for birds and other wildlife. They often host rare or endangered plants.

Detention of runoff water is an important depressional wetland function because runoff, or occasional overbank flooding in riparian depressions, alters flood timing, duration, and magnitude. The result is reduced flood flow downstream. Water storage or detention has significant effects on biogeochemical cycling; plant distribution, composition and abundance; and wildlife populations. Just as in riverine wetlands, nutrient cycling is mediated primarily by two processes: (1) nutrient uptake by plants (primary production), and (2) nutrient release from dead plants for renewed uptake by plants (detrital turnover). Because of their location on the landscape, depressional wetlands, particularly those in lower portions of watersheds, are strategically located to remove and sequester sediments, imported nutrients, contaminants, and other elements and compounds before they can contribute to ground water and surface-water pollution downstream. These contaminants are removed from incoming water by the interaction of water, wetland vegetation, wetland microbes, detrital material, and soil. The primary benefit of this function is that the removal, conversion, and sequestration of compounds by depressional wetlands reduces the load of nutrients and pollutants in ground water and in any surface water leaving the depressional wetland. Not all depressions are positioned or capable of removing these sediments, compounds, and contaminants. For instance, depressions at the top of drainage basins, or those in flat topography, may not receive pollutants from upstream.

Depressional wetlands support many animal populations. They provide habitats within the actual wetland and in conjunction with the surrounding landscape. They maintain regional biodiversity by providing open water, nesting cavities, cover and food chain support for a variety of animals (Ewel 1998). In some regions, Carolina bays are major and critical focal points for breeding and feeding of a large variety of nonaquatic vertebrate and invertebrate animal species. The biomass of animals in these Carolina bays is extremely high compared to adjacent terrestrial habitats or more permanent aquatic habitats (Richardson and Gibbons 1993).

Forested wet flats—In the Southern United States, wet flats occur on poorly drained mineral or organic soils in lowland areas (Harms and others 1998, Rheinhardt and others 2002). Wet flats on organic, or peaty, soils are called pocosins. Pocosins differ from mineral-soil flats in both geomorphology and vegetation. Pocosins are located on topographic highs and are dominated by evergreen shrubs, and most burn every 15 to 30 years (Rheinhardt and others 2002, Richardson 1981). The hydrologic regime of pocosins is driven by precipitation, but water flows outward from the center and eventually forms headwater streams near the wetland's outer boundaries (Brinson 1993). The organic soils of pocosins tend to hold water longer than mineral-soil flats. As a result, frequency of fire is less than in mineral-soil flats.

Mineral-soil flats are most common on areas between rivers, extensive lake bottoms, or large floodplain terraces where the main source of water is abundant precipitation and slow drainage associated with a landscape of low relief (Brinson 1993, Rheinhardt and others 2002). This class predominantly occurs on the Atlantic Coastal Plain from Virginia to Texas (fig. 20.1). There are two subclasses of mineral-soil flats: those dominated by a closed canopy of hardwoods, and those characterized by open savanna with widely scattered pines (Rheinhardt and others 2002). Mineral-soil hardwood flats in the

Yazoo Basin of Mississippi occur on former and current floodplains created by the Mississippi River and its tributaries (Smith and Klimas 2002). Mineral-soil flats receive virtually no ground-water discharge. This characteristic distinguishes them from depressions. The dominant direction of water movement is downward through infiltration. These wetlands lose water by evapotranspiration, surface runoff, and seepage to underlying ground water. They are distinguished from flat upland areas by their poor drainage due to impermeable layers (hardpans), and slow lateral drainage. Mineral-soil pine flats will be the focus of the following discussion due to the millions of acres that still exist and their susceptibility to alteration due to fire exclusion, development, and silvicultural conversion to pine plantation.

The pre-European landscape was largely maintained by fires resulting from lightning strikes and Native American burning. However, with the colonization and subsequent management by Europeans, less than 2 percent of the fire-maintained character of mineral-soil pine flats remained by the 1990s. In their least altered condition, wet pine flats have very few trees. When trees are present, longleaf, pond, and occasionally slash and loblolly pines are naturally associated with this wetland type. All four pines can tolerate ground fires by the time they reach 6 to 9 feet in height, but longleaf is the only pine whose seedlings are adapted to tolerate fire. The combined stresses of fire and wetness led to the evolution of an unusually rich flora on many wet pine flats (Rheinhardt and others 2002).

Wet pine flats differ from other wetlands due to a combination of factors that do not occur together in any other wetland type. These factors combine to control the biogeochemical processes characteristic of wet pine flats:

1. The source of water, dominated by precipitation and vertical fluctuations in water level driven by evapotranspiration, is generally low in nutrients.

2. When flooding occurs, it is shallow (10 to 20 cm) and flows slowly.

3. The number of pits and mounds on the ground surface is high and provides a diverse array of aerated and anoxic conditions for soil microbial organisms.

4. Nutrient recycling occurs in pulses following fires, which recur on a frequent basis, thus enabling a rapid turnover of nutrients. These four attributes enable wet pine flats to tightly and rapidly cycle nutrients. As a result, wet pine flats rapidly recover their characteristic biomass and structure after fires (Rheinhardt and others 2002).

Plant communities characteristic of unaltered wet pine flats are maintained by an appropriate hydrologic regime, fire regime, and biogeochemical processes that require intact soil conditions. Under relatively unaltered conditions, these three parameters combine to maintain a grassy savanna with few or no trees. On some sites, the herbaceous plant community is extremely rich. In fact, the herbaceous species richness is the highest recorded in the Western Hemisphere (Walker and Peet 1983). This herbaceous assemblage is extremely sensitive to alteration and, as a consequence, many species associated with this ecosystem are rare or threatened with extinction. Because the herbaceous community of wet pine flats is so sensitive to alteration (fire exclusion, hydrologic alteration, and soil disturbance), its condition provides information on habitat quality. Plant populations in wet pine flats have evolved to both withstand and require frequent fire. Fire stimulates flowering and seed set in many wet savanna species, such as toothache grass and wiregrass. As a result, species composition and spatial habitat structure reflect fire frequency. In the absence of fire, wet pine flat vegetative composition becomes dominated by shrubs or hardwood trees. This is a degraded condition when compared to a fire-maintained wet pine flat.

Animals that use unaltered wet pine flats for all or part of their lives are adapted to habitats maintained by frequent fire. Frequent fire maintains open savanna, which is important to some animal species using wet pine flats. For animal species that utilize both unaltered wet pine flats and other similar fire-maintained landscapes, the total area of fire-maintained landscape (both wetland and upland) is critical. Because fire frequency has been drastically reduced in most areas of the Southeast, many animal species that require habitat maintained by frequent fire are threatened or endangered over most of their historic range. Maintenance of a characteristic animal assemblage depends upon: (1) habitat quality within the site (onsite quality), and (2) the quality of the surrounding landscape that provides supplemental resources (landscape quality). Onsite habitat quality can be inferred from the structure and composition of the plant community.

A number of species rely on fire-maintained pine ecosystems of which wet flats are a part. For example, birds and other wide-ranging animals that rely on fire-maintained systems do not appear to differentiate wet pine flats from uplands, as long as both are fire-maintained. Thus, fire-maintained uplands supplement resources available in fire-maintained wet flats and vice versa.

Alterations to Forested Wetlands Due to Development, Agriculture, and Silviculture

Functions of forested wetlands and the concomitant goods and services they provide can be degraded or destroyed by human activities. Activities that affect forested wetlands fit into four broad categories: (1) urban development, (2) rural development, (3) agriculture, and (4) silviculture. Since each wetland impact carries a unique set of circumstances and responses, these categories are rather gross. Their use, however, helps to describe wetland status, trends, and impacts in the South.

NWI defines urban development as intensive use in which much of the land is covered by structures, including buildings, roads, commercial developments, power and communication facilities, city parks, ball fields, and golf courses. In rural development, land use is less intensive, and the density of structures is more sparse. Agriculture is defined as land use primarily for the production of food and fiber, including horticultural, row, and close-grown crops as well as animal forage. Silviculture is defined here as management of land for production of wood (Dahl 2000).

The replacement of forested wetlands with urban and/or rural development constitutes an irreversible loss, since the wetland is replaced by upland.

Developed areas lack wetland hydrology, soils, and vegetation, either singly or in any combination. Changing a forested wetland to an agricultural field typically changes its hydrology and vegetation and disturbs its soil. However, some of these agricultural activities, such as drainage and removal of native vegetation, can be reversed and wetlands restored. Silvicultural activities typically do not lead to a loss of wetland status but may temporarily affect wetland functions. In forested riverine wetlands, for example, the overstory vegetation is removed but hydrology is left largely intact. Like some agricultural effects, silvicultural effects can be reversed and the wetland functions restored. More specific aspects of these activities will be discussed next.

Urban and rural development—The effects of urban and rural development on riverine, flat, and depressional wetlands in the South are similar. Forest vegetation is cleared, areas are drained or filled to escape flooding, structures are built, and wetland vegetation is replaced. These activities eliminate the ability of forested wetlands to store and convey surface water and ground water. Water runs off these developed surfaces faster, reaching streams quicker and contributing to larger floods downstream. Development also eliminates the water-quality enhancement of forested wetlands. Development alters the hydrology and replaces the soils and vegetation with manmade structures which are not able to take up excess nutrients and other pollutants. The structures may actually contribute pollutants to adjacent aquatic ecosystems. Basnyat and others (1999) reported that urban land is the strongest contributor of nitrate to adjacent streams in Alabama. Alteration of hydrology and replacement of vegetation and soils with manmade structures also eliminate the forested wetland plant community and the wildlife associated with these areas. In other words, urban and rural development typically replace the wetland with upland and developed land with none of the functions of wetlands and little chance of restoration.

Agriculture—Generally, agricultural activities in forested wetlands manipulate hydrology, remove native vegetation, and disturb the soils for the purpose of crop production. Drainage, channelization, and levee construction impact the flow of water to and from a wetland site in an effort to dry out the area. When wetlands are drained for agricultural use, they no longer function as wetlands (Mitsch and Gosselink 2000).

In riverine wetlands, hydrology is the principal force for maintaining ecological processes and vegetation structure (Gosselink and others 1990). Drainage and channelization allowed water to reach the wetland but removed it from the site and/or watershed more quickly. Levees prevent floodwaters from reaching the wetland at natural intervals (once to several times per year). Thus, drainage, channelization, and levee construction result in changes in the timing of delivery of water (frequency), the amount of water delivered (magnitude), and the length of time the water remains in the wetland (duration). Duration of inundation is important in nutrient cycling, removal of pollutants and sediments, and export of organic carbon. Changes in hydroperiod also change the plant community, which alters the living and dead plant biomass components of nutrient cycling and organic carbon export. Construction of drainage ditches and channelization can affect the flow of subsurface water in a riverine wetland by changing the gradient of subsurface flow. Typically the result is a lower water table in the vicinity of the ditch or deepened channel. A shallower water table affects the ability of the riverine wetland to gradually contribute to stream flows during dry periods. Lowering the water table also affects biogeochemical processes and plant and animal communities that depend on the maintenance of a stable ground-water table (Ainslie and others 1999).

By impairing the ability of overbank flows to reach riverine wetland sites, levees prevent elements and compounds and sediments from reaching the wetland where they are deposited or removed. Levees prevent flood flows from transporting organic carbon to downstream aquatic ecosystems. They also act as barriers to aquatic species that use the floodplains for spawning and rearing (Baker and Kilgore 1994, Lambou 1990).

Clearing the native vegetation of a forested riverine wetland and replacing it with a crop dramatically reduces the site's structural diversity, wildlife-food-producing capacity, and nesting and escape cover (Gosselink and others 1990). Clearing also affects forest patch dynamics by decreasing forest patch size, interrupting forest continuity, decreasing the percentage of regional forested wetland, and increasing edge between community types. Soil tilling is likely to decrease the amount of organic matter in the soil due to oxidation. It also reduces water infiltration by creating a plow pan (Drees and others 1994). Therefore, clearing of native vegetation and forest structure and repeated plowing and tilling have the aggregate effect of causing more water to run off farm fields, contributing greater flows and nonpoint-source pollutants (Basnyat and others 1999).

Many Carolina bays have been significantly altered by agricultural practices, and some are being used for wastewater treatment (Richardson and Gibbons 1993). Managing forested depressions for agriculture involves clearing existing vegetation, installing drainage ditches through the rim of the Carolina Bay, tilling the soil, and planting the site in the desired crop species. Draining the depression alters the duration of ponding and the amount of water in the wetland. Plants, animals, and the biogeochemistry of the wetland are affected. Disrupting the surface of the soil by tilling affects the amount of organic material in the soil. As water is drained from the depression, soil organic material is exposed to the air, speeding its removal through oxidation. As soils are disturbed and more organic carbon is exposed from deeper in the soil and more is oxidized as a result, the balances among water, carbon, and other elements like nitrogen and phosphorous are disrupted. Accumulation of too much sediment in depressional wetlands, from erosion in nearby uplands, decreases wetland water storage volume, decreases the duration of water retention in wetlands, and changes plant community structure by burial of seed banks. As with riverine wetlands, clearing the existing vegetation in Carolina bays alters the composition and structure of the native plant community and affects wildlife species that utilize the depression.

Sharitz and Gresham (1998) report that 97 percent of the Carolina bays in South Carolina have been disturbed by agriculture (71 percent), logging (34 percent), or both. Agriculture is the oldest and predominant use of bays, having started in the 1940s. Soils in Carolina bays are highly organic and have a high nutrient-holding capacity. They are attractive to farmers if drainage is accomplished; soil pH is raised by liming; minor nutrients tied up by the highly organic soils are supplied to the crops with spray; and weeds are controlled, primarily with herbicides. If these activities are completed, Carolina bays are 10 to 15 percent more productive than upland soils, but these activities alter the structure and function of the Carolina bay.

Organic soil flats were cleared and drained for agriculture as early as the 1780s. Several large pocosins have been impacted by corporate agricultural operations, which have drained, limed, and fertilized these wetlands for corn and soybean production. Offsite effects of draining pocosins for agriculture included decreased salinity in adjacent estuaries; increased turbidity in adjacent streams immediately after development; and increased phosphate, nitrate, and ammonia inputs into adjacent streams and estuaries, particularly when runoff volumes are high (Sharitz and Gresham 1998). These problems can be minimized by managing the water levels in the drainage ditches with risers, which maintain water tables and slow the delivery of water to adjacent streams and estuaries. In 1989 14 percent of pocosins in North Carolina were owned by corporate agriculture and 36 percent by major timber companies (Richardson and Gibbons 1993). Originally pocosins covered 2,244,000 acres in North Carolina, but by 1980 this had been reduced by 739,000 acres due to agriculture, silviculture, and development (Richardson and Gibbons 1993). Clearing pocosins for agriculture is no longer practiced due to restrictions placed on landowners by the Food Security Act and section 404 of the Clean Water Act.

Silviculture—Silvicultural activities in forested riverine wetlands typically consist of clearcutting overstory vegetation and allowing natural regeneration from sprouts (Kellison and Young 1997, Lockaby and others 1997b, Walbridge and Lockaby 1994). The stand then progresses from a thicket dominated by briars, vines, and tree seedlings and sprouts to a sapling stage after 10 to 20 years, to a pole timber stage after 20 to 30 years, to a small saw-log stage at 30 to 50 years, and finally to a mature forest stage beyond age 50 (Kellison and Young 1997). Hydrologic responses to this silvicultural regime typically are short-term elevations in the water table due to a reduction in evapotranspiration (Lockaby and others 1997b, Sun and others 2001). Removing the trees reduces the amount of the soil water transpired by plants, and the water then fills more soil pores, resulting in a water-table rise. However, this reduction in evapotranspiration is typically negated by the sprouting vegetation on the clearcut site within 2 years (Lockaby and others 1997a). Another hydrologic effect of harvesting riverine wetlands is soil compaction which interferes with the movement of water through the soil. Lockaby and others (1997) determined that the hydraulic conductivity of the saturated soil was reduced 50 to 90 percent in the ruts caused by skidding of logs. This effect can be temporary, depending on the soil type and hydrology of the wetland (Perison and others 1997, Rapp and others 2001).

There is concern that harvesting and site preparation in wetlands cause or contribute to the generation of nonpoint-source pollutants, particularly sediment. Ensign and Mallin (2001) found that when compared to an upstream reference site, a stream in the Coastal Plain of North Carolina experienced higher levels of nutrients (nitrogen and phosphorous), higher fecal coliform levels, and recurrent algal blooms for up to 15 months after clearcut harvesting of adjacent forested wetlands. The authors speculated that these effects were due to the inability of the clearcut wetland site to retain and transform upstream agricultural pollutants. However, other studies indicate the magnitude of these effects is small and the longevity is brief (Lockaby and others 1997b, Messina and others 1997, Shepard 1994, Walbridge and Lockaby 1994). Studies indicate that after revegetation, sediment deposition in wetlands is actually greater on harvested sites because the amount of vegetation is greater, thus slowing floodwaters to a greater degree and allowing more sediment to drop from the water column (Aust and others 1997, Perison and others 1997).

The capacity of forested riverine wetlands to act as sinks, sources or transformers of nutrients and carbon, depends upon landscape position, the amounts of nutrients entering the wetland, and the time since disturbance. The degree to which silviculture affects a riverine wetland's capacity to transform nutrients and sequester other pollutants is uncertain (Lockaby and others 1997b). Conceptually, riverine wetlands serve as sinks when they receive high inputs of nutrients. They may serve as sources when disturbed to the point where active oxidation of soil organic matter or export of mineral sediment is occurring, and they may serve as transformers in relatively undisturbed situations. However, Lockaby and others (1999) point out that few generalizations can be made about biogeochemical cycling and nutrient retention functions because of the variable nature of responses of riverine wetlands to harvests, and the inability of current scientific methods to detect subtle biogeochemical changes due to silvicultural activities. Thus, they conclude that the ability to predict whether long-term shifts in biogeochemical transformations occur due to silviculture is minimal and that there is a critical need to understand how silviculture affects the enhancement of water quality in riverine wetlands.

Perhaps the most apparent effect of silvicultural operations on forested riverine wetlands is the removal of the tree canopy. The ability of the forested wetland to recover from harvesting is of interest to both forest industry and conservation interests. Generalizations about the productivity of forested riverine wetlands and their ability to recover from harvests are difficult due to the diversity of forested wetlands. Different moisture regimes, hydrologic conditions, and soil types have resulted in the diversity of wetland types (Conner 1994). Comparisons between harvested sites and reference sites require long-term study. A study conducted 1 year after harvesting in a Texas riverine wetland showed little difference in the composition of tree species regenerating on the harvested site and the presence of those species on an unharvested site (Messina and others 1997). Another study conducted

7 years after harvest in a tupelo-cypress riverine wetland indicated that harvested stands were stocked with tree species similar to the reference. The stand harvested by helicopter had an even distribution of overstory species, while the stand harvested with ground-based methods was dominated by tupelo gum (Aust and others 1997). In a study conducted 8 years after harvesting a riverine wetland in South Carolina, no difference between the species composition of the overstory of harvested and unharvested stands was detected. However, midstory and understory vegetation differed between the two treatments (Rapp and others 2001). These authors concluded that the effects of harvesting are short-lived and that these stands will return to pretreatment species composition. Additional long-term research is needed to continue to track the development of the plant community and ecological functions in harvested stands compared with unharvested stands.

Wildlife species have a variety of ecological roles that contribute to the maintenance of the forested riverine wetland. Wildlife contributes to the dispersal of plants by caching and transporting seeds, and they alter forest structure and composition by eating vegetation and creating impoundments. They alter soil and forest productivity by burrowing and preying on macroinvertebrates. They support food webs, transport energy to surrounding ecosystems, and recolonize adjacent habitats (Wigley and Lancia 1998). Biotic and abiotic factors determine the inherent capacity of a forested wetland to support a community of wildlife species. Soils, topography, hydrology, disturbance, climate, stand vegetation, landscape pattern of habitats and land uses, wildlife community interactions, and human-related alteration of forest structure and composition affect the abundance of wildlife (Wigley and Lancia 1998). The contribution of wildlife to ecological processes and the factors influencing wildlife presence are complex. As a result, evaluating the effects of clearcutting with natural regeneration on riverine wetlands is difficult.

At the stand scale, the vertical and horizontal dimensions of forest structure are important, because the more layers present from the forest floor to the canopy and the taller they are, the more opportunities for foraging, nesting, and escaping from predators (Wigley and Lancia 1998). As plant succession proceeds in forested wetlands, structural diversity tends to increase, but the frequency and duration of flooding may reduce the mid- and understory vegetation. Thus, some animals needing lower layers of the forest, such as the wood thrush, hooded warbler, and Swainson's warbler, may not be present in natural forest stands (Howard and Allen 1989). However, flooding may contribute to vertical diversity by creating snags, which are important to some species like the prothonatary warbler, wood ducks, woodpeckers, and bats (Wigley and Lancia 1998). Horizontal diversity refers to the distribution of vegetation or other structural features in patches throughout the stand. This horizontal diversity can provide habitat for early successional species in a mature stand or mature stand species in an early successional stand. Diversity of mast-producing species can also ensure a consistent food supply. When production of one tree species is low, that of another species may be high.

Edges occur between wetland forest types, wetland and upland forest types, or between land uses. The effects of these edges vary. Edges can increase species diversity by providing habitat for the species in the abutting habitats plus those species that prefer edges. On the other hand, edges can increase predation and brood parasitism by brown-headed cowbirds and add exotic species (Wigley and Lancia 1998). Riverine wetlands can serve as regional migration corridors for black bear, neotropical songbirds, and waterfowl (Gosselink and others 1990). However, these corridors can aid in the conveyance of species from one habitat to another or, as with edges, can convey predators, diseases, and parasites. Forested wetlands also fit into a landscape mosaic of habitat types that may be important to species needing several habitats to fulfill life requirements. Species presence and productivity are sometimes viewed as functions of the size and shape of a wetland habitat patch, amount of edge, distance from patches of similar habitat (isolation), amount of time since isolation, and immigration and dispersal of animals from habitats (Wigley and Roberts 1997). However, much of the landscape-scale information on the effect of these wildlife habitat functions on the presence and productivity of wildlife populations is based on theory. Few data exist for managed forest landscapes to validate these theories (Wigley and Lancia 1998; Wigley and Roberts 1994, 1997).

Riverine forested wetlands have an abundance of detritus, hard and soft mast, snags, cavity trees, and large woody debris on the ground as well as multilayered vegetation, and these typically support conditions rich and diverse wildlife communities (Ainslie and others 1999, Gosselink and others 1990, Wigley and Lancia 1998). Forest management activities potentially influence wildlife habitat at site-specific and landscape scales. Clearcuts with natural regeneration temporarily reduce availability of hard mast and canopy and cavity trees (Wigley and Roberts 1994, 1997). However, regeneration of woody vegetation and ground vegetation growth typically increase after harvest, downed woody debris often increases due to harvesting (assuming it is not windrowed and burned), and early successional wildlife species may increase. Clawson and others (1997) found that amphibian population diversity and abundance were only temporarily affected by harvesting. Thus, many habitat alterations due to forest management are temporary.

From a landscape perspective there is a growing recognition that the lack of early successional forest, including but not exclusive to forested wetland, is limiting biodiversity in the Eastern United States (Hunter and others 2001, Litvaitis 2001, Thompson and Degraaf 2001, Trani and others 2001, Wigley and Roberts 1997). Thompson and Degraaf (2001) suggest that silvicultural operations can contribute to landscape diversity by creating early successional habitats in forested landscapes. Several studies have suggested that in largely forested landscapes, early successional patches increase wildlife diversity (Thompson and others 1992, Welsh and Healy 1993). However, as previously pointed out, little is known of the effects of forest management in landscapes permanently fragmented by conversion to agriculture or urban development.

Silviculture: depressions—Sharitz and Gresham (1998) note that managing Carolina bays for timber requires clearing the existing vegetation, installing drainage ditches within the bay and through the rim, bedding the bay soil, and planting trees. Any of these activities greatly alters the structure and function of the bay ecosystem.

Pondcypress swamps are harvested for sawtimber and increasingly for landscape mulch. Typically, they are harvested by clearcutting. Clearcuts regenerate well (Ewel and others 1989), but leaving some mature trees to produce seed is advocated due to uncertainty of resprouting and seed production (Ewel 1998). After harvesting, water levels in pondcypress swamps typically rise, and amphibian and wading bird usage of the post-harvest swamp increases. Mammal usage also changes, with fewer nest and den sites but more prey available (Ewel 1998).

Silviculture: mineral-soil pine flats—On mineral-soil flats, three parameters stand out as being essential for determining the degree to which ecosystem processes are altered by a given impact: (1) the alterations in the hydrologic regime, (2) alterations in fire regime, and (3) alterations in the soil. These changes in ecosystem processes on mineral-soil flats alter plant and animal habitats. Hydrologic fluctuations determine the composition of fire-tolerant vegetation, and soil conditions control the dynamics of biogeochemical transformations by soil microbes. Fires maintain open, sometimes treeless savannas by precluding species that would otherwise shade out characteristic savanna plants and provide nutrients in discrete pulses utilized by savanna plants (Rheinhardt and others 2002).

Silvicultural impacts on flat wetlands typically include surface and subsurface drainage, ditching, harvest and mechanical reduction of native vegetation, bedding, which alters microtopographic relief, and the construction of roads (Harms and others 1998). The objective of intensive management on these mineral-soil flat wetlands is to produce pine plantations. Most biogeochemical processes in wetlands depend on the distribution and timing of flooded and dry conditions. Draining a mineral-soil flat eliminates flooding and soil saturation, which in turn alters processes that depend on flooded conditions, including fermentation, and denitrification.

With the exception of artificial drainage, most alterations to hydrologic regime are localized in their effect on biogeochemical processes and habitat quality. For example, a dam (even a low one such as a road fill) can impede surface flow and back water up over a large area. One result is a longer period of inundation. Input of excess water from offsite can likewise increase the duration and depth of water levels. Alterations to water balance change the duration and timing of flooding and the saturation of soil in the upper horizons. In contrast, artificial drainage reduces inundation periods. Artificial drains transport water, nutrients, and dissolved organic matter into streams downstream, altering the water flow and chemistry for a period of 2 to 3 years. (Amatya and others 1997, Beasley and Granillo 1988, Lebo and Herrmann 1998). However, these studies also indicate that the hydrologic effects of ditches can be ameliorated with water-control structures such as flashboard risers (Sun and others 2001).

Soil condition on mineral-soil flats also can be affected by intensive silvicultural activities (Miwa and others 1997, 1999). Microbial organisms and plants are adapted to characteristic microtopographic structure, soil texture, and nutrient regime. Alterations to soils affect these conditions upon which soil microbes and plants depend. The result may be a change in biogeochemical cycling processes. For example, harvesting under wet conditions can affect water-holding capacity and available water for plant growth and slow internal soil drainage, causing higher water tables and slower site drainage in the immediate area of the harvest (Miwa and others 1997). Bedding is currently the best available technique to ameliorate these effects. However, bedding also may affect soil-bulk density both on the beds and in the trenches between, thus altering interstitial pore space and substrate conditions on which soil microbes and plants depend. In addition, microtopographic variation is changed by a regular distribution of small, low (10 to 20 cm high), regularly distributed hummocks to a parallel array of trenches and high ridges (15 to 30+ cm high). On bedded sites, duration and frequency of flooding are increased in trenches and decreased on beds relative to unaltered conditions, which result in altered rates, timing, and magnitudes of biogeochemical processes (Rheinhardt and others 2002).

Mechanical treatment of native vegetation and bedding a mineral-soil flat to produce pine plantations affects fire-maintained wildlife habitat of wet pine flats. For example, several amphibian species are associated with fire-maintained landscapes and travel across wet flats to breeding ponds in cypress depressions. There is evidence that intensive silviculture may detrimentally affect amphibian and reptile populations (Rheinhardt and others 2002), because intensive silviculture relies on a series of raised parallel-aligned beds on which pine seedlings are planted. Standing water in the troughs between beds may cue amphibians to lay their eggs in these troughs, where water sits for too short a time to support larval development, rather than in deeper, more permanent cypress depressions which are commonly scattered throughout wet pine flats.

Policy

Development, agriculture, and silviculture are regulated primarily by two Federal laws: the Food Security Act (Public Law 104-127) (FSA), and the Clean Water Act (CWA). The objective of the “Swampbuster” provision of the FSA is to discourage alteration of wetland hydrology, vegetation, and soils to facilitate production of commodity crops (Strand 1997). FSA penalizes landowners who alter wetlands for this purpose by removing their eligibility for Federal subsidies. However, agricultural landowners may retain their eligibility for benefits by restoring, enhancing, or creating wetlands to compensate for lost wetland functions and values.

Development, agriculture, and silviculture are also regulated under section 404 of the CWA. Section 404 requires that anyone proposing to place fill material into waters of the United States, including wetlands, must obtain a permit from the U.S Army Corps of Engineers (COE). In order to obtain a permit the applicant must show: (1) why the project cannot be located somewhere besides a wetland, (2) why the project will not adversely harm the wetland, and (3) what the applicant will do (if granted the permit) to offset the loss of wetland functions and values. Replacement of lost wetland functions and values is typically accomplished through mitigation—the restoration, enhancement, or creation of wetlands in another location. For a more indepth discussion of these laws see chapter 8.

Under section 404 (f) of the CWA, normal silvicultural and agricultural activities, such as plowing, seeding, cultivating, minor drainage, and harvesting for the production of food, fiber, and forest products, are exempt from the permitting requirements. However, these activities must be part of an ongoing agricultural or silvicultural operation and may not change a wetland to an upland. In addition, construction of forest roads is exempt under section 404(f) as long as 15 federally prescribed best management practices (BMPs) are implemented. The issues surrounding forest road construction and the BMPs used to ameliorate water-quality impacts of roads are discussed further in chapter 22. In 1995, the U.S. Environmental Protection Agency (EPA) and the COE issued guidance on BMPs for mechanical site-preparation activities for the establishment of pine plantations. This guidance established the circumstances where mechanical silvicultural site-preparation activities required a section 404 permit as well as those where no permit is required (U.S. Environmental Protection Agency 1995). In general, sites which are wet for a large portion of an average year [i.e., permanently flooded, intermittently exposed, semipermanently flooded, or seasonally flooded (bottomland hardwoods)] require a permit for mechanical site-preparation activities. Sites which are wet for only a portion of the year [i.e., seasonally flooded (higher elevation in the floodplain) intermittently flooded, temporarily flooded, or saturated hydrology] do not require a permit as long as BMPs, discussed in the guidance, follows.

Restoration

Approximately half of the South's forested wetlands have been lost in the last 200 years. Along with this loss in acreage has been the loss of wetland functions and societal benefits, goods, and services described in the last section. In an attempt to ameliorate the environmental damage of wetland loss, restoration of former forested wetlands is being attempted throughout the South. Wetland restoration is defined by the Society of Wetland Scientists as "actions taken in a converted or degraded natural wetland that result in the establishment of ecological processes, functions, and biotic/abiotic linkages and lead to a persistent, resilient system integrated within its landscape." The goal of restoration of wetland ecosystems was expressed by the National Research Council (1992) as "returning the system to a close approximation of the predisturbance ecosystem that is persistent and self-sustaining (although dynamic in its composition and functioning)." Therefore, since much of the forested wetland loss in the past has been due to agriculture, any national or regional program designed to restore millions of acres of former wetlands will have to focus primarily on wetlands converted to agricultural use (National Research Council 1992). Presumably these agricultural lands would still occupy the same landscape position and have the same or similar hydrology as the original wetlands prior to conversion. An exception to this is in areas where extensive levee systems like those in the Lower Mississippi Valley have restricted flooding on a broad scale.

Although forested wetlands have been lost throughout the South, perhaps the most acute losses have been in the Lower Mississippi Alluvial Valley (LMAV). There, approximately 18 million acres of wetland were lost to agricultural conversions (King and Keeland 1999). Such conversions have involved clearing the natural forested wetland vegetation, drainage, and flood control. In the LMAV, the estimated original 25 million acres were reduced to approximately 5 million acres by 1978 (Hefner and Brown 1985). Ninety-six percent of the forested wetland losses in the LMAV were due to agriculture; the remaining losses were due to construction of flood control structures, surface mining, and urbanization (Schoenholtz and others, in press).

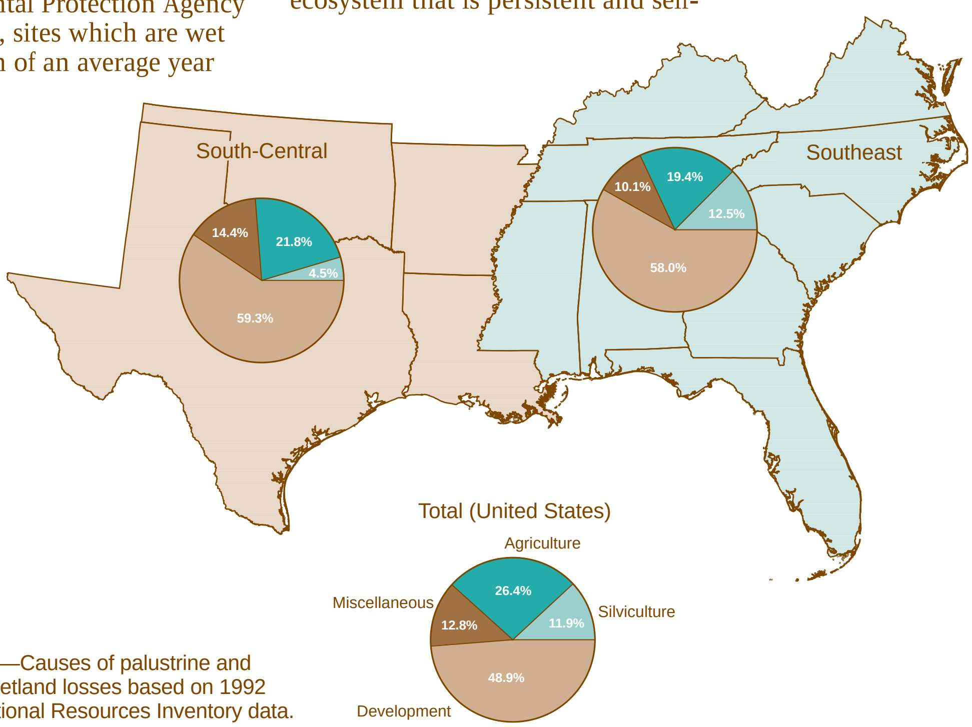

Figure 20.3—Causes of palustrine and estuarine wetland losses based on 1992 to 1997 National Resources Inventory data.

Table 20.5—Wetland Reserve Program acres by State in the South as percent of national and regional totals

State	Total WRP acres	National total WRP acres	Southern total WRP acres
		Percent	
Virginia	1,063	0.12	0.219
North Carolina	18,216	1.99	3.751
South Carolina	13,507	1.48	2.781
Georgia	7,374	.81	1.518
Florida	45,225	4.94	9.312
Kentucky	7,613	.83	1.568
Tennessee	13,976	1.53	2.878
Alabama	1,410	.15	.290
Mississippi	92,107	10.06	18.965
Arkansas	87,664	9.58	18.050
Louisiana	132,319	14.46	27.245
Oklahoma	30,304	3.31	6.240
Texas	34,892	3.81	7.184
Total	485,670	53.07	100.000

WRP = Wetland Reserve Program.

In the 1970s and 1980s the U.S. Fish and Wildlife Service recognized the trend in forested wetland loss and associated habitat impacts in the LMAV and began a campaign to reestablish forested wetlands in the LMAV (King and Keeland 1999). The development of the WRP by NRCS as well as smaller projects undertaken by the COE and State Fish and Game agencies has intensified reforestation/restoration in the LMAV, making this area the largest reforestation/restoration effort in the South. Figure 20.3, derived from NRI data from 1982 to 1992, indicates that 17.5 percent of the watersheds in the South experienced a gain of forested wetland, 31.2 percent experienced a loss, and 51.3 percent experienced no change. However, it is uncertain if the acres reported in the NRI represent actual acres restored versus acres enrolled in WRP.

The WRP of the 1990 Farm Bill is directed at wetland systems and provides for conservation easements for 10 to 30 years. The 1990 Farm Bill, which was reauthorized in 1996, established that up to 1 million of the 6 million acres of cropland eligible for the Conservation Reserve Program may be wetlands. This program, unlike most others, has the potential to restore large acreages of forested wetlands in the South.

King and Keeland (1999) reported that approximately 195,000 acres have been reforested in the LMAV. Restoration of forested wetland systems in the LMAV involves restoration of the geomorphic, hydrological, and ecological processes that drive these wetland systems. Massive forest clearing, construction of thousands of miles of drainage ditches, broad-scale channelization of streams and rivers, flood prevention, and farming practices have changed hydrology, topography, and soils. Restoration of wetland functions is extremely difficult there. Table 20.5 shows that 64 percent of the WRP acres are in the States of Mississippi, Louisiana, and Arkansas. Presumably, all or a major portion are in the LMAV. Figure 20.4 shows the number of WRP acres by State in the South. Once again, Mississippi, Louisiana, and Arkansas have the greatest number of farmers enrolled. In addition to WRP acres, the U.S. Fish and Wildlife Service has planted approximately 59,000 acres and State Wildlife Management Areas have planted 28,000 acres (Schoenholtz and others, in press). Information could not be found to document restoration efforts in other parts of the South. Programmatic success of restoration is determined by the number of trees surviving (greater than 125 per acre) on a WRP site after 3 years. Ecological success is difficult to determine and, due to the protracted nature of forested wetland restoration, will continue to be difficult to determine in the future.

Currently, restoration has attempted to reestablish forested wetland hydrology and vegetation on sites where these two characteristics have been removed. Thus, much of the restoration effort has been directed toward agricultural land. However, some wetland ecosystems, namely mineral-soil pine flats, have been ecologically degraded by exclusion of natural disturbances like fire. Restoration of wetland ecologic processes, functions, and biotic/abiotic linkages could be achieved if the disturbance

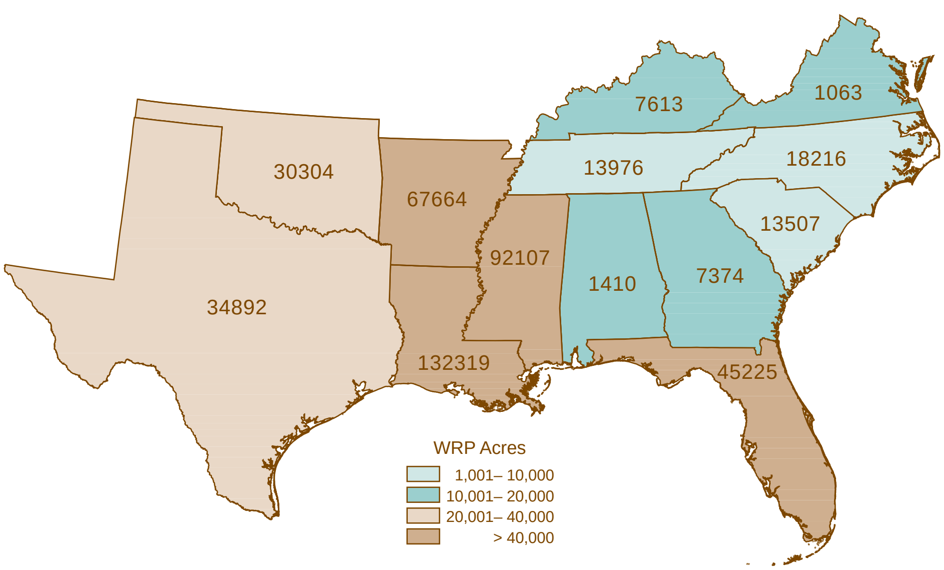

Figure 20.4—Number of acres enrolled in WRP Program based on 1992 to 1997 Natural Resources Inventory data.

regime were reestablished. Lorimer (2001) points out the important role fire has historically played in maintaining plant species composition and structure in the South and its effects on wildlife abundance and distribution. Thompson and DeGraaf (2001) suggest that historic disturbance regimes can provide effective models for silviculture by substituting harvesting for fire. In largely forested regions like the Northeastern and mid-Atlantic United States, harvesting can promote early successional growth and increase biodiversity (Hagan and others 1997, Thompson and others 1992, Welsh and Healy 1993). However, restoration of mineral-soil pine-flat wetlands can best be achieved by reestablishing frequent fire into these ecosystems.

Section 404 of the CWA regulations establishes procedures for permitting the discharge of solid fill material into wetlands. This program is administered primarily by the COE with oversight from the EPA. If impacts due to these permitted activities are considered to be unavoidable, restoration of former wetlands is typically required to offset losses. Restoration of forested wetlands is a typical requirement of the section 404 permitting program. Although many small-scale wetland restoration projects have been required in the history of the section 404 program, the COE and EPA maintain no systematic accounting of these projects or their success.

Few consistent data are available to track the amount of forested wetland mitigation that has been required or the amount that has actually been completed. It is even more difficult to ascribe success to many of the mitigation efforts that have been undertaken. Two studies in the South found that many of the mitigation projects proposed and carried out under the section 404 program did not replace the wetlands originally impacted (Morgan and Roberts 1999, Pfeifer and Kaiser 1995). The National Research Council (1992) listed the following as reasons for unsuccessful mitigation in a regulatory context:

1. Poor design of mitigation projects by individuals lacking sufficient expertise to address the complexities of wetland ecosystems.

2. Landowners often prepare the least expensive and least time-consuming plan acceptable to the regulatory agencies leading to half-hearted attempts to restore wetlands.

3. Wetlands restored in the regulatory context are often small in size, widely separated from other wetlands, and threatened by adjacent land uses.

4. After initial restoration, wetland mitigation sites receive very little management.

For these reasons wetlands restored in the regulatory context may be less likely to achieve restoration goals. A recent report on compensating for wetland losses under the CWA concluded that the goal of no net loss of wetlands is not being met for wetland functions by the section 404 mitigation program, despite progress over the last 20 years (National Research Council 2001).

Discussions and Conclusions

Forested wetlands provide a variety of hydrologic, biogeochemical, and habitat functions unique to these ecosystems. Landscape position, water, soils, and plants all contribute to the structure and function of forested wetlands in the South. All these contributions can be degraded by human impacts. Status and trends indicate that the rates of wetland losses in general are down to 356,000 acres (2.3 percent) for the period of 1986–97. According to NWI, approximately 119,000 acres of forested wetland have been lost to urban/rural development, 112,000 acres to agriculture, and 102,000 acres to silviculture. Approximately 3 million acres of forested wetland were converted by silvicultural operations to different (forest) wetland types. Timber harvests in the South are expected to increase over the next 20 years. Since almost one-fourth of the timberland in the South is forested wetland, it is likely that impacts to forested wetlands as a result of intensified silviculture will continue, and perhaps additional acreage will be affected in the future. Silvicultural operations affect the hydrologic and structural characteristics of wetlands. However, when hydrology is not permanently altered and sites are allowed to regenerate naturally, indications are that, in time, they function similarly to unaltered wetlands. Sites converted to intensive pine plantation culture experience longer term changes to their structural and biotic diversity.

There is a great deal of potential for restoration of forested wetlands on former agricultural land in the South. The WRP and the section 404 program provide opportunities to restore these former wetlands. However, forested wetland restoration is a complex undertaking, and must be done carefully to recreate the lost functions and values of forested wetlands in the South.

Needs for Additional Research

1. Landscape-level studies are needed to determine the causal mechanisms for wildlife and water-quality response to landscape configurations and features such as corridors. We need to know how forest treatments affect wildlife and plant communities and stream water quality in the various types of wetlands in landscapes predominated by riverine forests, a mix of riverine and upland forests, a variety of wetland types (e.g., Coastal Plain where riverine, depression, and flat classes occur together in close proximity), and a variety of land uses (agriculture, urban/rural, etc.). Information from this type of research should be integrated with research from site-specific scales.

2. Research is needed on the water-quality enhancement and plant ecological functions of forested wetlands and the impacts of forest practices on those processes in different wetland classes.

3. At present, three Federal agencies—the U.S. Fish and Wildlife Service, the NRCS, and the USDA Forest Service—collect landscape-scale wetlands data. However, due to different data objectives and agency missions, much of this data is incompatible for tracking status and trends of forested wetlands. A unified database of this information is needed.

4. Cause and effect research is needed by HGM class, at the site-specific and landscape scale on representative sites across the region.

5. Long-term monitoring of restoration and mitigation is needed by HGM class at representative sites across the South.

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Literature Cited

Abernethy, Y.; Turner, R.E. 1987. U.S. forested wetlands: 1940–1980. Bioscience. 37(10): 721–727.

Ainslie, W.B.; Smith, R.D.; Pruitt, B.A. [and others]. 1999. A regional guidebook for assessing the functions of low gradient, riverine wetlands in western Kentucky. Tech. Rep. WRP–DE–17. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station. 216 p.

Allen, A.W.; Bernal, Y.K.; Moulton, R.J. 1996. Pine plantations and wildlife in the Southeastern United States: an assessment of impacts and opportunities. Tech. Rep. 3. Washington, DC: U.S. Department of the Interior, National Biological Service. 32 p.

Amatya, D.M.; Skaggs, R.W.; Gregory, J.D.; Herrmann, R.B. 1997. Hydrology of a drained forested pocosin watershed. Journal of American Water Resources Association. 33(3): 535–546.

Askins, R.A. 2001. Sustaining biological diversity in early successional communities: the challenge of managing unpopular habitats. Wildlife Society Bulletin. 29(2): 407–412.

Aust, W.M.; Schoenholtz, S.H.; Zaebst, T.W.; Szabo, B.A. 1997. Recovery status of a tupelo-cypress wetland 7 years after disturbance. Forest Ecology and Management. 90: 161–169.

Baker, J.A.; Killgore, K.J. 1994. Use of a flooded bottomland hardwood wetland by fishes in the Cache River System, Arkansas. Tech. Rep. WRP–CP–3. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station, Wetlands Research Program. [Number of pages unknown].

Basnyat, P.; Teeter, L.D.; Flynn, K.M.; Lockaby, B.G. 1999. Relationships between landscape characteristics and nonpoint source pollution inputs to coastal estuaries. Environmental Management. 23(4): 539–549.

Beasley, R.S.; Granillo, A.B. 1988. Sediment and water yields from managed forests on flat Coastal Plain sites. Water Resources Bulletin. 24(2): 361–365.

Brady, S.J.; Flather, C.H. 1994. Changes in wetlands on non-Federal rural land of the conterminous United States from 1982 to 1987. Environmental Management. 18(5): 693–705.

Brinson, M. 1993. A hydrogeomorphic classification for wetlands. Vicksburg, MS: U.S. Army Corps of Engineers. 92 p.

Brinson, M.M. 1990. Riverine forests. In: Brinson, M.M.; Lugo, A.E.; Brown, S., eds. Forested wetlands. Amsterdam: Elsevier Scientific Publishers: 87–141.

Brinson, M.M.; Rheinhardt, R.D. 1998. Wetland functions and relations to societal values. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 29–48.

Brown, M.J.; Smith, G.M.; McCollum, J. 2001. Wetland forest statistics for the south Atlantic States. Resour. Bull. SRS-62. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 52 p.

Clawson, R.G.; Lockaby, B.G.; Jones, R.H. 1997. Amphibian responses to helicopter harvesting in forested floodplains of low order, blackwater streams. Forest Ecology and Management. 90: 25–235.

Conner, W.H. 1994. Effect of forest management practices on southern forested wetland productivity. Wetlands. 14(1): 27–40.

Conner, W.H.; Buford, M.A. 1998. Southern deepwater swamps. In: Massina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC. [Number of pages unknown].

Cowardin, L.M.; Carter, V.; Golet, F.C.; Roe, E.T. 1979. Classification of wetlands and deepwater habitats. Vol. FWS/OBS–79/31. Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service. 131 p.

Dahl, T.E. 1990. Wetlands: losses in the United States 1780s to 1980s. [Place of publication unknown]: U.S. Department of the Interior, U.S. Fish and Wildlife Service. [Number of pages unknown].

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. [Place of publication unknown]: U.S. Department of the Interior, U.S. Fish and Wildlife Service. [Number of pages unknown].

Delcourt, P.A.; Delcourt, H.R.; Morse, D.F.; Morse, P.A. 1993. History, evolution, and organization of vegetation and human culture. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley. 502 p.

Dickson, J.G. 1991. Birds and mammals of pre-colonial southern old-growth forests. Natural Areas Journal. 11(1): 6–33.

Drees, L.R.; Karathanasis, A.D.; Wilding, L.P.; Blevins, R.L. 1994. Micromorphological characteristics of long-term no-till and conventionally tilled soils. Soil Science Society of America Journal. 58: 508–517.

Ensign, S.H.; Mallin, M.A. 2001. Stream water quality changes following timber harvest in a Coastal Plain swamp. Water Research. 35: 1–10.

Ewel, K.C. 1990. Swamps. In: Myers, R.L.; Ewel, J.J., eds. Ecosystems of Florida. Orlando, FL: University of Central Florida Press: 281–323.

Ewel, K.C. 1998. Pondcypress swamps. In: Messina, M.G.; Conner, W.H., ed. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 405–420.

Ewel, K.C.; Davis, H.T.; Smith, J.E. 1989. Recovery of Florida cypress swamps from clearcutting. Southern Journal of Applied Forestry. 13(3): 123–126.

Frayer, W.E.; Hefner, J.M. 1991. Florida wetlands: status and trends, 1970s to 1980s. Atlanta: U.S. Fish and Wildlife Service. 31 p.

Frayer, W.E.; Monahan, T.J.; Bowden, D.C.; Graybill, F.A. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950s to 1970s. Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences. 32 p.

Gosselink, J.G.; Lee, L.C.; Muir, T.A. 1990. Ecological processes and cumulative impacts illustrated by bottomland hardwood wetland ecosystems. Chelsea, MI: Lewis Publishing. 708 p.

Hagan, J.M.; McKinley, P.S.; Meehan, A.L.; Grove, S.L. 1997. Diversity and abundance of landbirds in a northeastern industrial forest. Journal of Wildlife Management. 61(3): 718–735.

Hammond, E.H. 1970. Physical subdivisions of the United States of America. In: U.S. Geological Survey: national atlas of the United States of America. Washington, DC: Department of the Interior. 61 p.

Harms, W.R.; Aust, W.M.; Burger, J.A. 1998. Wet flatwoods. In: Messina, M.G.; Conner, W.H., ed. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 421–444.

Harris, L.D.; Gosselink, J. G. 1990. Cumulative impacts of bottomland hardwood forest conversion on hydrology, water quality, and terrestrial wildlife. In: Lee, L.C.; Gosselink, J.G.; Muir, T.A., eds. Ecological processes and cumulative impacts illustrated by bottomland hardwood wetland ecosystems. Chelsea, MI: Lewis Publishers: 259–322.

Hefner, J.M.; Brown, J.D. 1985. Wetland trends in the Southeastern United States. Wetlands. 4: 1–11.

Hefner, J.M.; Wilen, B.O.; Dahl, T.E.; Frayer, W.E. 1994. Southeast wetlands: status and trends, mid-1970s to mid-1980s. Atlanta: U.S. Fish and Wildlife Service. 33 p.

Hodges, J.D. 1998. Minor alluvial floodplains. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 325–342.

Howard, R.J.; Allen, J.A. 1989. Streamside habitats in southern forested wetlands: their role and implications for management. In: Hook, D.D.; Lea, R., eds. Proceedings of the symposium: the forested wetlands of the Southern U.S. Gen. Tech. Rep. SE–50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 97–106.

Hunter, W.C.; Buehler, D.A.; Canterbury, R.A. [and others]. 2001. Conservation of disturbance-dependent birds in Eastern North America. Wildlife Society Bulletin. 29(2): 440–455.

Kellison, R.C.; Young, J. 1997. The bottomland hardwood forest of the Southern United States. Forest Ecology and Management. 90: 101–115.

Kellison, R.C.; Young, M.J.; Braham, R.R.; Jones, E.J. 1998. Major alluvial floodplains. In: Messina, M.G.; Conner, W.H., ed. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 291–323.

King, S.L.; Keeland, B.D. 1999. Evaluation of reforestation in the Lower Mississippi Valley. Restoration Ecology. 7(4): 348–359.

Lambou, V.W. 1990. Importance of bottomland hardwood forest zones to fish and fisheries: the Atchafalaya Basin, a case study. In: Lee, L.C.; Gosselink, J.G.; Muir, T.A., eds. Ecological processes and cumulative impacts: illustrated by bottomland hardwood forests. Chelsea, MI: Lewis Publishers: 125–193.

Lebo, M.E.; Herrmann, R.B. 1998. Harvest impacts on forest outflow in coastal North Carolina. Journal of Environmenatl Quality. 27(6): 1382–1395.

Litvaitis, J.A. 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin. 29(2): 466–473.

Lockaby, B.G.; Clawson, R.G.; Flynn, K. [and others]. 1997a. Influence of harvesting on biogeochemical exchange in sheetflow and soil processes in a eutrophic floodplain forest. Forest Ecology and Management. 90: 187–194.

Lockaby, B.G.; Stanturf, J.A. Messina, M.G. 1997b. Effects if silvicultural activity on ecological processes in floodplain forests of the Southern United States: a review of existing reports. Forest Ecology and Management. 90: 93–100.

Lockaby, B.G.; Trettin, C.C.; Schoenholtz, S.H. 1999. Effects of silvicultural activities on wetland biogeochemistry. Journal of Environmental Quality. 28(6): 1687–1698.

Lorimer, C.G. 2001. Historical and ecological roles of disturbance in Eastern North American forests: 9,000 years of change. Wildlife Society Bulletin. 29(2): 425–439.

Messina, M.G.; Conner, W.H. 1998. Southern forested wetlands: ecology and management. 1st ed. Boca Raton, FL: Lewis Publishers. 616 p.

Messina, M.G.; Schoenholtz, S.H.; Lowe, M.W. [and others]. 1997. Initial responses of woody vegetation, water quality, and soils to harvesting intensity in a Texas bottomland hardwood ecosystem. Forest Ecology and Management. 90: 201–215.

Mitsch, W.J.; Gosselink, J.G. 2000. Wetlands. 3rd ed. New York: Van Nostrand Reinhold. 920 p.

Miwa, M.; Aust, W.M.; Burger, J.A. [and others]. 1999. Harvesting and site preparation effects on the hydroperiods of wet flat pine plantations. In: Haywood, James D., ed. Proceedings of the tenth biennial silvicultural research conference. Gen. Tech. Rep. SRS–30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 293–297.

Miwa, M.; Aust, W.M.; Burger, J.A.; Patterson, S.C. 1997. Characterization of disturbed forest soils in the lower Coastal Plain of South Carolina. In: Waldrop, Thomas A., ed. Proceedings of the ninth biennial silvicultural research conference. Gen. Tech. Rep. SRS–20. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 379–385.

Moorhead, K.; Russell, I.M. 1998. Southern mountain fens. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 379–404.

Morgan, K.L.; Roberts, T.H. 1999. An assessment of wetland mitigation in Tennessee. Cookerville, TN: Tennessee Technological University and Tennessee Department of Environment and Conservation, Division of Water Pollution Control. [Number of pages unknown].

National Research Council. 1992. Restoration of aquatic ecosystems. Washington, DC: National Academy Press. 552 p.

National Research Council. 2001. Compensating for wetland losses under the Clean Water Act. Washington, DC: National Academy of Sciences. [Number of pages unknown].

Perison, D.; Phelps, J.; Pavel, C.; Kellison, R. 1997. The effects of timber harvest in a South Carolina blackwater bottomland. Forest Ecology and Management. 90: 171–185.

Pfeifer, C.E.; Kaiser, E.J. 1995. An evaluation of wetlands permitting and mitigation practices in North Carolina. Raleigh, NC: University of North Carolina, Water Resources Research Institute. [Number of pages unknown].

Rapp, J.; Shear, T.; Robison, D. 2001. Soil, groundwater, and floristics of a Southeastern United States blackwater swamp 8 years after clearcutting with helicopter and skidder extraction of timber. Forest Ecology and Management. 149: 241–252.

Rheinhardt, R.D.; Rheinhardt, M.C.; Brinson, M.M. 2002. Regional guidebook for applying the hydrogeomorphic approach to wet pine flats on mineral soils in the Atlantic and Gulf Coastal Plains. ERDC/EL TR-02-9. Vicksburg, MS: U.S. Army Engineer Research and Development Center. 220 p.

Richardson, C.J., ed. 1981. Pocosin wetlands. Stroudsberg, PA: Hutchinson Ross Publishing. [Number of pages unknown].

Richardson, C.J.; Gibbons, J.W. 1993. Pocosins, Carolina bays, and mountain bogs. In: Boyce, S.G.; Martin, W.H.; Echternacht, A.C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 257–310.

Schoenholtz, S.H.; James, J.P.; Kaminski, R.M. [and others]. [In press]. Status and trends in afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley. Wetlands.

Sharitz, R.R.; Gresham, C.A. 1998. Pocosins and Carolina bays. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 343–377.

Sharitz, R.R.; Mitsch, W.J. 1993. Southern floodplain forests. In: Martin, W.H.; Boyce, S.G.; Echternacht, A.C., ed. Biodiversity of the Southeastern United States: lowland terrestrial communities. 1st ed. New York: John Wiley: 311–372.

Shepard, J.P. 1994. Effects of forest management on surface water quality in wetland forests. Wetlands. 14(1): 18–26.

Shepard, J.P.; Brady, S.J.; Cost, N.D.; Storrs, C.G. 1998. Classification and inventory. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. Boca Raton, FL: CRC Press LLC: 1–28.

Smith, R.D.; Ammann, A.; Bartoldus, C.; Brinson, M.M. 1995. An approach for assessing wetland functions using hydrogeomorphic classification: reference wetlands, and functional indices. Vicksburg, MS: U.S. Army Corps of Engineers. 77 p.

Smith, R.D.; Klimas, C.V. 2002. A regional guidebook for applying the hydrogeomorphic approach to assess wetland functions of selected regional wetland subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley. ERDC/EL TR-02-4. Vicksburg, MS: U.S. Army Engineer Research and Development Center. [Number of pages unknown].

Strand, M.N. 1997. Wetlands deskbook. 2d ed. Washington, DC: Environmental Law Institute: 27–30, 73–76.

Sun. G.; McNulty, S.G.; Shepard, J.P. [and others]. 2001. Effects of timber management on the hydrology of wetland forests in the Southern United States. Forest Ecology and Management. 143: 227–236.

Thompson, F.R.; DeGraaf, R.M. 2001. Conservation approaches for woody, early successional communities in the Eastern United States. Wildlife Society Bulletin. 29(2): 483–494.

Thompson, F.R.; Dijak, W.D.; Kulowiec, T.G.; Hamilton, D.A. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. Journal of Wildlife Management. 56: 23–30.

Trani, M.K.; Brooks, R.T.; Schmidt, T.L. [and others]. 2001. Patterns and trends of early successional forests in the Eastern United States. Wildlife Society Bulletin. 29(2): 413–424.

Walbridge, M.R.; Lockaby, B.G. 1994. Effects of forest management on biogeochemical functions in southern forested wetlands. Wetlands. 14(1): 10–17.

Walker, J.; Peet, R.K. 1983. Composition and species diversity of pine-wiregrass savannas of the Green Swamp, North Carolina. Vegetation. 55: 163–179.

Welsh, C.J.E.; Healy, W.M. 1993. Effect of even-aged timber management on bird species diversity and composition in northern hardwoods of New Hampshire. Wildlife Society Bulletin. 21: 143–154.

Wigley, T.B.; Lancia, R.A. 1998. Wildlife communities. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands: ecology and management. 1st ed. Boca Raton, FL: CRC Press LLC: 205–236.

Wigley, T.B.; Roberts, T.H. 1994. A review of wildlife changes in southern bottomland hardwoods due to forest management practices. Wetlands. 14(1): 41–48.

Wigley, T.B.; Roberts, T.H. 1997. Landscape level effects of forest management on faunal diversity in bottomland hardwoods. Forest Ecology and Management. 90: 141–154.

U.S. Army Corps of Engineers. 1987. Wetlands delineation manual. Tech Rep. Y–87–1. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station. [Number of pages unknown].

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 1995. Memorandum to the field on application of best management practices to mechanical silvicultural site preparation activities for the establishment of pine planta-tions. http://www.epa.gov/owow/wetlands/silv2.html. [Date accessed: August 21, 2002].

How have forest management activities and other forest uses influenced water quality, aquatic habitat, and designated uses in forested watersheds?

Chapter 21: Forestry Impacts on Water Quality

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Key Findings

- In the absence of controlling measures such as Best Management Practices (BMPs), silvicultural operations have the potential to significantly impact general water quality by generating nonpoint-source pollution.
- From 1988 to 1998, an annual average of approximately 3,600 miles of rivers and streams were considered potentially impaired by pollution from silvicultural activities throughout the South.
- When compared with other land uses in the South, silvicultural activities are consistently found to be minor nonpoint sources of water-quality impacts (see chapter 19). Silviculture was one of the lowest "leading sources" of pollution or impairment for rivers and streams between 1988 and 1998 as reported by Southern States.
- BMPs are critical in mitigating water-quality degradation from silviculture. When appropriately implemented and maintained, BMPs are very effective in controlling nonpoint sources of pollution. They are particularly important in areas with steep topography.
- On an individual site basis, most water-quality impacts are short term (first several years after harvest), decreasing over time as vegetation regrows. However, there is very little information available on the cumulative effects of past and ongoing timber harvesting on overall watershed health.
- The major potential nonpoint-source impact resulting from silvicultural activities is sediment from roads and skid trails. Other minor nonpoint-source impacts on water quality include short-term increased peak flows during storms; short-term increased base flows; short-term increased nutrient concentrations (primarily nitrogen and phosphorous); short-term increases in herbicides, fertilizers, and derivative products; and thermal pollution (increased stream temperature).

Introduction

The quality of water draining forested watersheds in the South is typically the highest in the country (Brown and Binkley 1993, Clark and others 2000). For this reason, the effects of forestry activities on water quality have been widely studied (Brown and Binkley 1994; National Council for Air and Stream Improvement 1994, 1999; Riekerk and others 1989; Stickney and others 1994; Swank and others 1989). It has been found that pollution impacts on water quality from forestry activities are generally local in nature, short-lived, less frequent, and less extensive in nature than activities related to either agricultural or urban activities (Bethea 1985, Dissmeyer 2000). For a complete discussion on various types and sources of pollution and the relative impacts of silvicultural versus other land use activities on water quality in the South (see chapter 19). Chapter 8 describes the many laws and regulations governing silvicultural nonpoint-source impacts on water quality.

Without adequate controls, however, forestry operations do have the potential to significantly affect high-quality water sources and critical fisheries habitat. Silvicultural operations that can cause nonpoint-source pollution include road and skid trail construction, tree cutting and removal, site preparation and stand regeneration treatments, herbicide application, fertilizer application, and prescribed burning. The major types of potential pollutants produced by these sources include sediment, logging equipment fluids, nutrients from harvested areas and applied fertilizers, forestry pesticides, and increased water temperature or thermal pollution.

This chapter describes how forest management activities and pollutants influence water quality. Prior to the enactment of the Clean Water Act (CWA) in 1972, research on forest water quality examined the impacts of forestry activities characterized by the absence of controls over how and where trees were cut or how they were removed. Since that time, however, water-quality research has begun to focus on the effectiveness of BMPs for maintaining water quality while harvesting trees. In response to the CWA, there is a growing body of research on the effectiveness of BMPs in protecting water quality. Chapter 22 specifically describes the range of appropriate silvicultural BMPs and addresses the effectiveness of BMPs in protecting water quality in the South.

While there is a considerable amount of overlap between chapters 15, 19, 20, 22, and 23, this chapter focuses specifically on the impacts of silvicultural activities on water. From public meetings and written comments obtained when the Assessment was being planned, a list was compiled of major points to address in this chapter. These included:

- Evaluate how these activities have influenced and can influence hydrologic response.
- Include a consideration of all relevant water-quality parameters: biological, chemical, and physical.
- Examine effects of pesticides, sediment, and fertilizer.
- Examine the influence of these activities on municipal water supplies.
- Discuss how impacts may differ depending on the size and intensity of harvest and other treatments.
- Identify any differences in water-quality impacts of hardwood versus pine management and plantations versus natural stands.

Each of these items is discussed in the "Results" section of this chapter, with the exception of the influence of forestry activities on municipal water supplies and designated uses (for a definition of designated uses, see chapter 19). Specific information on these topics was not identified during research conducted for this chapter. However, the impacts of individual water-quality pollutants, including sediment, nutrients, and pesticides/herbicides resulting from forestry activities on designated uses, such as drinking water supply, primary contact recreation, or wildlife habitat, are generally discussed in sections related to individual pollutants.

Methods and Data Sources

Existing literature, which is extensive, was reviewed to describe impacts from silvicultural activities on water quality. Given the magnitude of the study area and the generally localized nature of water-quality impacts from silviculture, the primary objective for this chapter was to compile an extensive, current summary of literature on the subject. No original research was conducted.

Primary data sources include Federal agency reports, academic and professional journals, and workshop proceedings. An attempt was made to: (1) identify the most recent literature on the subject matter, and (2) identify appropriate references and studies that have been completed across the entire 13-State study area.

Results

Brown and Binkley (1994) compiled an extensive review of land management impacts on water quality in North America. They concluded that there is the potential for forestry operations to adversely affect water quality if BMPs are poorly implemented. Without adequate controls, forestry operations may degrade several water-quality characteristics in water bodies receiving drainage from forests (Mostaghimi and others 1999). Sediment concentrations can increase due to accelerated erosion; water temperatures can increase due to removal of overstory riparian shade; slash and other organic debris can accumulate in water bodies, depleting dissolved oxygen; and organic and inorganic chemical concentrations can increase due to harvesting and fertilizer and pesticide applications (Brown 1985). These potential increases in contaminants are usually proportional to the severity of site disturbance (Riekerk 1985, Riekerk and others 1989). Impacts of silvicultural nonpoint-source pollution depend on site characteristics, climatic conditions, and the forest practices employed.

The U.S. Environmental Protection Agency (EPA) publishes a biennial national assessment of water quality, summarizing State reports that are based on monitoring, surveys of scientists, water-quality modeling, and citizen input. EPA National Water Quality Inventory Reports from 1988 to 1998 reported an annual average of approximately 3,600 miles of rivers and streams that were considered potentially impaired by nonpoint-source pollution from silviculture activities throughout the South (table 21.1). An impaired water is defined as any water body that is classified as partially supporting, or not supporting, its designated use(s) (see chapter 19). From 1988 to 1998, Mississippi reported the greatest average number of river and stream miles per year (1,216 miles) that were considered impaired by forestry activities, followed by Louisiana (984 miles) and Florida (563 miles). Texas did not report any river and stream miles as being impaired by forestry activities during this timeframe. Georgia reported an average of one river and stream mile per year as being impaired by silvicultural activities.

The information displayed in table 21.1 represents an aggregation of current, localized water-quality problems that have been partially or wholly attributed to silvicultural activities and reported by individual States. Given the magnitude of the study area, it was not possible to identify and summarize the extent of these localized problems for this report.

Table 21.1 highlights the extreme variability in river and stream miles impaired by silvicultural activities as identified by States. Because of this variability, the National Association of State Foresters (NASF) and the Society of American Foresters (SAF) conducted a thorough review of water bodies listed as impaired by silvicultural operations (Society of American Foresters 2000). In their review, they concluded that EPA and the States overestimated the amount of waters affected by silviculture. The study cited two major problems with the listing process: (1) inconsistent data reporting and (2) insufficient water-quality data. There is a great deal of interstate variability in how State reports are compiled. For example, some States may simply identify silviculture as a general source of nonpoint-source pollution; other States may distinguish between different silvicultural operations such as road building, site preparation, herbicide application, etc. (Society of American Foresters 2000). In addition, some listings are a result of deforestation rather than silviculture. An instance is cited in Louisiana where the actual cause of impairment was deforestation for residential development rather than forestry operations.

Clearly there is uncertainty regarding the accuracy of State listings of impairment due to silviculture. Despite these limitations, this information represents the most comprehensive set of current water-quality data available for the South. These reports were used in this chapter to identify general trends over time at the regional and State levels. A more thorough discussion of the EPA National Water Quality Inventory Reports and the relative importance of

Table 21.1—Total river miles impaired by silviculture in the South (1988-98)

State	Impaired river miles[a] 1988	1990	1992	1994	1996	1998	Average 1988-98[b]
Alabama	0	196	218	195	219	0	138
Arkansas	0	261	193	251	218	0	154
Florida	63	142	154	1,181	1,410	428	563
Georgia	0	—	—	—	3	0	1
Kentucky	—	—	34	120	103	56	78
Louisiana	—	1,339	1,167	758	1,328	326	984
Mississippi	0	405	2,051	408	2,310	2,121	1,216
North Carolina	48	—	313	276	243	151	206
Oklahoma	20	—	126	126	110	218	120
South Carolina	4	—	—	326	221	221	193
Tennessee	140	142	—	74	524	61	188
Texas	—	—	—	—	—	0	0
Virginia	0	—	—	166	658	11	209
Total	275	2,485	4,256	3,881	7,347	3,593	3,639

— = not reported.

[a] A river mile includes all river and stream miles reported by each State. An impaired river mile is classified as partially supporting overall use or not supporting overall use.

[b] Average impaired miles from 1988 to 1998 is defined as the total of impaired miles for the years that data was reported divided by the number of years for which data was reported.

Source: U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998, 2000a (National Water Quality Inventory Reports to Congress).

silviculture as a source of water-quality problems is included in chapter 19.

The major impacts of silvicultural activities on water quality described here are: (1) changes in hydrological responses of watersheds, (2) increases in sedimentation, (3) increases in temperature, (4) reductions in dissolved oxygen content, (5) increases in nutrient content of streams, (6) effects on aquatic habitat and biota, and (7) effects on forested wetlands. A final section addresses the water-quality effects associated with silvicultural management intensity and specific site-preparation techniques, such as fertilizer or herbicide application and prescribed burning.

Hydrologic Response

Seven processes are at work in the terrestrial portion of the hydrologic cycle: condensation, precipitation, interception, infiltration, surface runoff, subsurface flow, and evapotranspiration. These occur simultaneously and, except for precipitation, continuously. Precipitation begins after water vapor becomes too heavy to remain in atmospheric air currents. During rainfall, some precipitation is caught on vegetative surfaces, and the water may evaporate before reaching the ground surface. This is moisture called interception. A portion of the precipitation that reaches the Earth's surface seeps into the ground through the process called infiltration. The amount of water that infiltrates the soil varies with rainfall intensity, the degree of land slope, the amount and type of vegetation, the soil and rock type, and whether the soil is already saturated with water. The more openings in the surface (cracks, pores, joints), the more infiltration occurs. Precipitation that reaches the surface of the Earth but does not infiltrate into the soil is called surface runoff. When there is a lot of precipitation, soil may become saturated with water, and additional rainfall can no longer enter it. Surface runoff will quickly drain into creeks, streams, and rivers, adding a large amount of water to their flow. Along the way, some water evaporates, percolates into the ground, or is used for agricultural, residential, or industrial purposes. The infiltrated water either moves by subsurface pathways to the stream system, or it is taken up by plants through their roots and transpired. Evapotranspiration is water evaporating from the ground and transpiring from plants, or the total water vapor added to the atmosphere.

Streamflow is water moving through a stream channel and is comprised of both baseflow and stormflow. Between storm events, streamflow is dominated by baseflow resulting from soil moisture and ground-water discharge to the channel (Hewlett 1961, Hewlett and Hibbert 1966). During and shortly after a storm, streamflow rises and then falls back toward baseflow conditions. Such pulses of water during storms are called stormflow. Changes in flows attributed to forestry activities (especially timber removal) are generally measured as an average change in inches of surface runoff, and then reported relative to a control watershed. Peak flow is the maximum flow rate that occurs in a specified period of time, usually across a year or during a storm. A perennial stream is one which flows throughout the year. Intermittent and ephemeral streams flow seasonally and during storms, respectively.

Silvicultural activities can impact the hydrologic cycle by affecting soil compaction, amount of vegetative soil cover, evapotranspiration, infiltration into soil, interception loss, soil moisture, and snow melt/accumulation

(Reid 1993). Timber removal can drastically change interception amounts for several years after harvest and temporarily alter the water balance of a watershed by reducing total evapotranspiration. In general, reduced evapotranspiration rates result in higher soil moisture, ground-water recharge, and streamflow (Ursic and Douglas 1979). Reduced evapotranspiration rates can also cause increased stormflows because soils are wetter at the start of each rainfall event. Increases in surface runoff can be attributed to many different factors, including amount of precipitation, antecedent climatic conditions such as drought, hurricanes, percent of timber removed, soil compaction, infiltration, and soil moisture.

Hydrologic changes after a timber harvest usually include increases in total water yield (baseflow plus stormflow) and total streamflow, higher water tables (Douglas and Helvey 1971, Likens and others 1970, Lynch and Corbett 1990, Mostaghimi and others 1999, Riekerk 1985, Ursic and Douglas 1979), and increases in total amount and timing of storm runoff and peak flow rates (Beasley and Granillo 1988, Blackburn and others 1986, Mostaghimi and others 1999, Swank and others 1988, Ursic 1991, Van Lear and others 1985).

Forestry activities can also impact hydrologic regimes by altering the land's topography. For example, tractor skid trails can channel and concentrate erosive flows. Shallow subsurface flows can also be influenced by the use of mechanical equipment for site-preparation and planting activities (Mostaghimi and others 1999, Scoles and others 1996). Minor drainage interruptions can occur when skid trails or road construction redirect flows from one drainage to another (Reid 1993).

Baseflow and stormflow—Numerous studies have demonstrated increased water yields in the form of both increased baseflow and stormflow in response to timber cutting. Increased baseflows and stormflows can increase channel scouring, erosion, and downstream deposition of eroded materials. Streamflow increases are approximately proportional to the percentage of trees removed (Patric 1978). Maximum increases in water yield result from clearcutting and extensive site preparation, which completely remove vegetation. Flows return to normal levels within several years as vegetation regrows (Bosch and Hewlett 1982, Hibbert 1966, Scoles and others 1996, Swank and others 1988, Swift and Swank 1981).

Rice and Wallis (1962) found that streamflow increased 2.08 inches relative to an undisturbed control watershed after the harvest of 2.8 million board feet and the construction of approximately 3 miles of new logging roads in a 4-square-mile watershed in the Sierra Nevada Mountains in California. In a worldwide survey of the literature on timber harvesting and water yield, Bosch and Hewlett (1982) found that cutting 10 percent of the pine forest on a watershed increased annual stormflow by approximately 1.6 inches in the first year after harvest. Harvesting 100 percent of the watershed increased flows between 7 and 20 inches during the first year after harvest.

Scoles and others (1996) reported that annual stormflows increased an average of 4 inches off both clearcut and selectively cut watersheds in the year after harvest in Arkansas compared to an uncut watershed. The increase was not statistically significant, however, due to the variability in stormflows between watersheds. In a different large-scale watershed study in Arkansas, Scoles and others (1996) found that average annual streamflow (corrected for rainfall) increased by 20 percent (3.9 inches) after 20 percent of the watershed was converted to pine plantation less than 10 years old, accompanied by a rapid expansion of the road network. Most of the total increase was seen during the dormant season (October through February). This increase in streamflow after conversion of hardwood forest to planted pine contrasts with the more usual result of decreased flows following conversion to pine (Swank and Douglas 1974, Swank and Miner 1968) (see section "Hardwood Conversion to Planted Pine"). This contrast may be due to the fact that the plantations described by Scoles and others (1996) were generally less than 10 years old and not transpiring at their maximum possible rate.

Lebo and Herrman (1998) examined outflow characteristics from 1986 to 1994 in a low-level pocosin site with artificial drainage in a 1,161-acre watershed on the Coastal Plain of North Carolina. They evaluated effects of semiannual road maintenance, timber harvest, site preparations, and replanting on water quality. Approximately 60 percent of the site was harvested during the study period. BMPs for the State of North Carolina were implemented where applicable. Although comparison of harvest and nonharvest years was complicated by variations in annual rainfall, the authors found that a 47-percent increase in outflow (4.33 to 6.40 inches) was associated with the harvesting of trees. The effects persisted for a year after the sites were prepared for planting.

There have been several exceptions reported in the literature where average annual stormflow on clearcut sites actually decreased following intensive site preparation compared to a control site (Mostaghimi and others 1999, Scoles and others 1996). Scoles and others (1996) reported decreased average annual stormflow in the first year after clearcutting and intensive site preparation on watersheds in Oklahoma. Those authors hypothesized that the unexpected decreases may have been due to subsoiling, a site-preparation method similar to deep plowing that creates soil furrows and often destroys soil texture, sealing large macropores created by old root channels, animal burrows, or soil cracks. Sealing of these macropores allows for collection of rainwater in the soil furrows with less draining of stormwater to ephemeral stream channels.

Similarly, Mostaghimi and others (1999) found that storm-runoff volumes were reduced after clearcutting and site preparation on sites in the Virginia Coastal Plain both with and without BMPs. The authors attributed the reduction of flows to the disruption of subsurface flow pathways from soil compaction and site-preparation activities similar to subsoiling.

Scoles and others (1996) found that the increases in stormflow off clearcut and selectively cut watersheds were greater than those off control watersheds during low-flow periods, primarily the growing season and fall. The increase in stormflow from harvested watersheds during the growing season is particularly evident because of the lack of water uptake from vegetation. The lack of vegetation often leads to soil saturation and, subsequently, greater volumes of water entering the stream system (Scoles and others 1996).

Peak flows—Research has generally concluded that forest harvesting has little influence on the size of a major peak flow (Hewlett and Helvey 1970). Scoles and others (1996) found that while peak flows increased with harvest intensity in several small watersheds in the Ouachita Mountains in Arkansas, the differences were not statistically significant. After large storms, peak flows did not differ much between an undisturbed watershed and a harvested area. They speculated that when there is significant rainfall and the soil is saturated with moisture, presence of vegetation in the watershed has less of an effect on mitigation of peak flows (Scoles and others 1996). However, soil and geologic features can produce wide variations in peak flows.

Sedimentation

Many studies have shown that the most important water-quality problem associated with forestry activities is sedimentation. Harvest and site-preparation techniques that expose bare soil to the erosional influence of raindrops have the greatest potential to impact water quality. Areas where soil has been disturbed are subject to erosion, resulting in the downslope movement of sediment after it rains. The movement of sediment downhill is related to the steepness of the slope and soil erodibility (National Council for Air and Stream Improvement 1994). Soil erodibility greatly influences the magnitude of soil erosion and transport. Factors that affect soil erodibility include soil texture, percent organic matter, presence of a litter layer, infiltration rate, and bulk density. Sources of sediment include roads and ditches (particularly at stream crossings), bare soil on steep slopes, cut banks, slope failures and debris flows, and streambank erosion and channel scour. For a more complete discussion of the factors influencing soil erosion and sedimentation (see chapter 22).

Fine sediments can impair habitat primarily by: (1) reducing the permeability of streambed gravels, which reduces water and gas exchange; (2) burying gravels, which inhibits or prevents the movement of organisms and materials between the stream channel and the river-influenced ground-water zone; (3) filling pools (National Council for Air and Stream Improvement 1994); and (4) covering salmonid nests, which prevents emergence and survival of fish fry (Waters 1995). Most timber harvest impacts are related to the access and movement of vehicles and machinery and the skidding and loading of trees or logs. Simply felling trees does not accelerate erosion much above geologic rates (Patric 1978). It does not compact the soil, and initially it actually adds to the litter layer. Revegetation is so quick in eastern hardwood forests that vegetation covers the soil within 2 to 3 years.

Harvesting activities that have the greatest erosion potential include the construction and use of haul roads, skid trails, and landings for access to and movement of logs, particularly in areas with steep slopes (Brown and Binkley 1994, National Council for Air Stream Improvement 1994, Patric 1978). Site preparation with large tractors that shear, disk, drum-chop, or root-rake a site usually result in considerable soil disturbance and compaction. Extensive vehicle movement removes vegetation and litter cover, which exposes and disturbs bare mineral soil. Harvesting and site-preparation activities can also create furrows and depressions that can capture and hold eroded soil. Decreased infiltration and percolation of precipitation may result in increased stormflows and runoff with high erosive forces. The retention of logging slash protects bare soil by intercepting rainfall, minimizing soil detachment.

Sedimentation impacts from forestry operations are generally short lived. Major impacts occur during and for several years after road construction activities—until road surfaces and cut-and-fill slopes stabilize. In examining the effects of logging on streamflow and sedimentation in a California watershed in the Sierra Nevada, Rice and Wallis (1962) reported that suspended sediment increased eightfold (from 0.25 to 4.12 tons per acre) in the first year after logging and dropped to 0.47 tons per acre, or twice its normal rate, by the second year.

Forestry professionals now commonly recognize that roads and skid trails are the major sources of sediment from forestry-related activities (Brown and Binkley 1994; Patric 1976; Swift 1984a, 1984b, 1988; U.S. Department of Agriculture, Forest Service 1984; Yoho 1980). Scoles and others (1996) report that up to 90 percent of stream sediment following timber harvesting is road related. Skidding logs across the forest floor exposes and compacts mineral soil, increasing chances of overland flow. Without overland flow there is no mechanism to carry detached soil particles to stream channels. Skidding many logs along the same track creates furrows that tend to channel and increase the erosive force of overland flows.

The Coweeta Hydrologic Research Laboratory began a series of watershed treatments in the 1940s to demonstrate the effects of timber harvesting on soil loss and water quality. These early studies emphasized the importance of roads and skid trails as sources of sediment to surface waters. Lieberman and Hoover (1948) reported that average stream turbidities during this Coweeta logging demonstration without BMPs were 96 parts per million (ppm), with a maximum turbidity level of 5,700 ppm during a storm in 1947. Typical logging practices in this era included steep access roads and skid trails constructed parallel and adjacent to streams. No controls were used to protect water quality. A control watershed exhibited average turbidities of 4.3 ppm with a maximum turbidity of 80 ppm. A second demonstration with extensive BMPs showed, by contrast, the value of erosion control practices (Dils 1957, Swift 1988).

Beasley and others (1984) related sediment loss associated with forest roads to the average slope gradient of road segments. The greater the average slope gradient, the greater the soil loss, ranging from a total of 6.8 tons per acre lost when the slope gradient was 1 percent, to 19.4 tons per acre at 4 percent, to 32.3 tons per acre at 6 percent, to 33.7 tons per acre at 7 percent. In addition, soil loss from roadbeds occurs primarily during the short period immediately after construction, but before the roadbed is completed and grass seed has become well established. In studies testing road design guidelines, one study found that three-quarters of the eroded soil was washed into the stream immediately below a road crossing during the first 2 months of the study; another 15 percent was measured a year later during the 3-month period when the road was being used for hauling logs (Swift 1988).

Road crossings over defined channels are the most critical points on a road system because fills are larger, the road drains directly into the stream system, and opportunities for mitigating practices are limited. Roadside ditches can also be a particularly large and direct source of sediment into streams and rivers (Reid and Dunne 1984, Sullivan and Duncan 1981). Spacing between drainage structures should decrease as slope increases to reduce the erosive power of ditch water (Scoles and others 1996, Swift and Burns 1999).

Careful location and layout of roads and logging operations can greatly affect the magnitude of sediment. Limiting equipment operation and construction of roads, skid trails, and landings also reduces the amount of sediment entering streams (Rice and Wallis 1962, Stringer and Thompson 2000). In an overview of road construction studies conducted at Coweeta, Swift (1988) describes the various components of road construction activities and compares their impacts. These studies developed improved road building techniques and other logging practices and demonstrate that logging roads could be built in the Appalachian Mountains without reducing water quality. In fact, current BMP guidelines for forest access roads are "almost without exception" based on Coweeta experience (Swift 1988). Soil loss can be reduced by up to 50 percent through proper planning and use of BMPs (Scoles and others 1996, Yoho 1980). A more thorough discussion of sediment impacts from roads and applicable BMPs is included in chapter 22.

Temperature

Many factors affect stream temperature, including incoming solar radiation; evaporation rates; topography; height and density of vegetation; amount of streamflow, depth and direction of flow; and temperature of water entering streams from subsurface flow (National Council for Air and Stream Improvement 1994, Scoles and others 1996). Forest practices may impact stream temperatures through: (1) the removal of streamside forest canopy, (2) alteration of the size and shape of stream channels, and (3) change in the volume of low flows (National Council For Air And Stream Improvement 1994). Increased temperatures in streams and water bodies can result from vegetation removal in the riparian zone. Aquatic organisms have adapted to seasonal variations in temperature, but temperature increases due to vegetation removal can be dramatic in small streams, adversely affecting aquatic species and habitat (Brown 1972, Curtis and others 1990, Megahan 1980). Increased water temperatures can: (1) reduce the amount of dissolved oxygen that a stream or water body can absorb, (2) increase aquatic metabolic rates, (3) increase biochemical oxygen demand, and (4) accelerate chemical processes (Curtis and others 1990). A 10 °C increase in stream temperature from 5 to 15 °C can double the metabolic rate of fish and other aquatic organisms, and reduce the saturation concentration for dissolved oxygen by approximately 20 percent (National Council for Air and Stream Improvement 1994).

The National Council for Air and Stream Improvement (1994) compiled temperature effects of complete canopy removal from a variety of studies across the United States. Increases in summer temperatures ranged from about 2 to 12 °C. In a study in central Pennsylvania (Lynch and others 1985), removal of riparian vegetation resulted in an increase in summer water temperatures of 5 to 11 °C, while the retention of riparian vegetation minimized the increase to 1 to 2 °C during the summer months. Beschta and others (1987) found that retaining canopy cover generally keeps temperature increases to less than 2 °C. Hewlett and Fortson (1982) found that clear-cutting in Georgia, while maintaining a partial buffer strip, increased average summer temperatures by 6.7 °C. Swift and Messer (1971) found that clearcutting in Appalachian Mountain cove hardwoods increased average summer maximum temperatures by 2.8 to 3.3 °C, while maintaining the overstory and simply cutting understory vegetation increased temperatures by only 0.3 °C.

Scoles and others (1996) found that the average water temperature in unshaded pools in three small streams in southeast Oklahoma following harvest was 3.6 °F higher at the water surface; temperatures at lower depths were unaffected. The streams were dry during the study except for a series of shallow pools (1 to 3 feet deep). Temperatures returned to normal downstream of the harvested area where ground-water inflow and streamside vegetation served to return temperatures to normal. Swift and Baker (1973) illustrate the cooling effects of shade strips contrasted with the stronger cooling by ground-water inflow.

Vowell (2001) reports that use of streamside buffers effectively maintained stream temperatures after clearcutting, intensive site preparation, and machine planting on four sites in northern Florida.

Only one study (Hewlett and Fortson 1982) reported major changes in stream temperatures after timber harvesting when riparian buffer strips were retained.

Dissolved Oxygen

Aquatic organisms need the oxygen dissolved in streamwater for metabolic activity. Dissolved oxygen concentrations can vary by stream because they depend on temperature and air pressure (elevation), as well as instream processes, including plant and animal respiration, oxygenation by means of gas exchange with the atmosphere, instream photosynthesis, and nutrient inputs. Dissolved oxygen concentrations vary diurnally due to instream plant and animal respiration. Concentrations of 8 mg per L are considered optimal for aquatic organism health (Chapman and McLeod 1987, U.S. Environmental Protection Agency 1986).

The impacts of forestry activities on dissolved oxygen levels in streambed sediments is less clear (National Council for Air and Stream Improvement 1994), but it seems likely that, in the absence of proper BMP implementation, increased fine sediment deposition may lead to decreased permeability of streambeds and thereby reduced intergravel oxygen concentrations (Chapman and McLeod 1987, Everest and others 1987). Reduced oxygen concentrations can lead to reduced viability of aquatic insects and fish eggs.

While there is limited research on this subject as it relates to forestry in the South, a few studies in Oregon (Hall and others 1987) and Quebec (Plamondon and others 1982) have documented that large inputs of fine litter to small, low-turbulence streams can deplete dissolved oxygen concentrations.

Vowell (2001) found that the use of BMPs in northern Florida adequately protected dissolved oxygen levels after clearcutting, intensive site preparation, and machine planting. Measurements before and after silvicultural treatments revealed no significant change in streamwater chemistry. Another study (Ensign and Mallin 2001) documenting the effects of forestry activities on dissolved oxygen is summarized in the section "Woody Wetlands."

Nutrients

Nutrient concentrations in streams flowing from forests vary widely depending on soil type and texture, parent material, climate, stand age, species composition, and atmospheric deposition. The U.S. Geological Survey conducted a national study of nutrient concentrations and yields in primarily undeveloped basins in an effort to more fully evaluate the effects of anthropogenic activities on water quality (Clark and others 2000). The majority of these basins were dominated by extensive forest cover and located primarily in wilderness areas, national and State parks, and national forests. The authors found that these basins produced the best water quality in the country. Concentrations of ammonia, nitrate, total nitrogen, orthophosphate, and total phosphorus rarely exceeded national water-quality standards.

Few nutrients are lost from healthy forest ecosystems directly to stream channels. These systems are very efficient at recycling nutrients. Young forests rapidly soak up nutrients from the soil as they grow (Borman and Likens 1994, Scoles and others 1996). The sudden removal of vegetation through timber harvesting or insect infestation, however, can increase the nutrient transport to streams by increasing leaching and erosion (Scoles and others 1996). Most increases in stream nutrient levels occur in the first few years after harvesting. Stream concentrations rapidly decline back to preharvest levels as vegetation regrows. In contrast, Swank and others (1981) and Swank (1988) reported small but persistent increases —as long as 20 years— in nutrient concentrations following insect defoliation and forest cutting. The effects of increases in nutrient inputs are often diluted by increases in stormflow after harvest (Scoles and others 1996). However, increases in streamflow can also lead to increases in total loading of nutrients to downstream areas, particularly lakes and reservoirs. The impacts of increased nutrients due to fertilization are discussed in the section "Effects of fertilizers, pesticides, and herbicides."

The primary nutrients affecting ecological processes in streams and lakes are nitrogen (primarily as nitrate) and phosphorus (primarily as phosphate) (National Council for Air and Stream Improvement 1994). Increases in nitrogen and phosphorous concentrations can increase stream productivity, increase daily fluctuations in stream oxygen concentrations, and increase or decrease species diversity. Excessive amounts of nutrients may also stimulate algal blooms. Large blooms limit light penetration into the water column, increase turbidity, and increase biological oxygen demand, resulting in reduced dissolved oxygen levels. This process, termed eutrophication, drastically affects aquatic organisms.

According to Binkley and Brown (1993), most forest harvesting studies in the United States have documented increased concentrations of nitrate after harvest. With a few exceptions, these increases have remained well below the 10-mg-per-L drinking water standard (U.S. Environmental Protection Agency 1986). This standard is appropriate for water bodies whose designated uses include municipal drinking water. However, aquatic communities respond to much lower levels of inorganic nitrogen. EPA is in the process of developing national nutrient standards for maintaining water quality that supports aquatic life and recreation as a designated use (U.S. Environmental Protection Agency 2000b).

One ecosytem region in the South that has been known to exceed the drinking water standard is high-elevation spruce-fir forest in the Southern Appalachian Mountains. Average nitrogen concentrations of 5 mg per L, with higher reported maximum values, occur in some streams in this area (Silsbee and Larson 1982). Factors possibly contributing to the elevated nitrogen concentrations include atmospheric nitrogen deposition and low nitrogen uptake rates due to the mature nature of these forests (Silsbee and Larson 1982). The Southern Appalachians receive relatively high rates of atmospheric nitrogen deposition compared to the rest of the region (Johnson and Lindberg 1992).

In a summary of several studies that considered the impacts of harvesting operations on nutrient inputs, Richter (2000) reported that streamwater nitrate nitrogen may increase up to 1 mg per L after harvest in the Appalachian Mountains (Swank 1988), the Atlantic Coastal Plain (Askew and Williams 1986, Riekirk 1983), the southern Piedmont (Hewlett and others 1984), and the Ouachita Mountains (Miller and others 1988).

In a study of the effectiveness of BMPs in northern Florida, Vowell (2001) reported that the State's BMPs adequately protected water quality. Streamwater chemistry, including total phosphorous, ammonia, nitrate, and nitrite, showed no significant differences before or after harvest.

Scoles and others (1996) reported that nitrogen and phosphorus levels increased the first year after harvesting but returned to baseline conditions within 4 years.

Ammonia generally is not a problem since it is found in low concentrations due to its high adsorptivity and ready conversion to nitrate. Several studies found little or no change in ammonia concentrations (Blackburn and Wood 1990, Martin and others 1984). One study (Van Lear and others 1985) reported decreases in ammonia concentrations after tree harvests. Decreases were attributed to increased nitrification due to increased soil temperature and moisture following harvest.

Mostaghimi and others (1999) found that harvest and site-preparation activities without the use of BMPs significantly increased nutrient loss during storms in the Virginia Coastal Plain. Stormflow concentrations and loadings of nitrogen and phosphorus increased significantly. Where BMPs were not applied, harvesting increased nitrogen loading by a factor of 3.1, and site-preparation activities increased it by a factor of 5.5. Use of BMPs mitigated these increases. In the absence of BMPs, total phosphorus in stormflow increased three- and fourfold following harvest and site-preparation activities, respectively, as compared to preharvest conditions. Stormflow phosphorus loading decreased 45 percent on the BMP watershed following harvest and did not change significantly after site preparation.

Aquatic Habitat and Biota

Fish and invertebrates depend on a variety of stream physical characteristics including temperature, dissolved oxygen, turbidity, light, nutrients, sediment particle size distribution, and refuge opportunities. Chapter 23 contains a complete discussion on the range of aquatic habitats and species in the South. Most studies on the impacts of silvicultural activities on aquatic biota and habitat have been conducted in the Pacific Northwest and northwestern California, areas dominated by steep slopes, frequent landslides, erodible soils, and high precipitation levels. Under these conditions, forest practices can have a substantial impact on stream channel conditions if BMPs are not fully implemented and maintained over time.

Sullivan and others (1987) document several case studies in northern California that took place between 1950 and 1970 when several extreme storms after extensive logging resulted in substantial alterations to stream channel morphology. Streambeds were raised by as much as 4 m, stream widths were doubled, stream channels were shifted, average particle size was increased, pools were filled in, riffles became less pronounced, summer flows were reduced, riparian vegetation was degraded, and stream banks were eroded. It was difficult to separate the contribution of harvesting impacts from the general storm effects, but fish populations declined over this period. In the 1982 National Fisheries Survey (Judy and others 1984), forestry activities were estimated to produce adverse effects on fish in about 7.5 percent of assessed river and stream miles, compared to 29.5 percent for agricultural land and 6.7 percent for urban areas.

Tebo (1955) studied the effects of early logging practices in steep mountainous watersheds on siltation and the impacts on bottom organisms in western North Carolina. There were no limitations on logging method, and the logging operations were not supervised by the USDA Forest Service. Tebo (1955) compared the number and volume of bottom-dwelling organisms upstream of the harvested area to a site located below the mouth of the stream draining the logged watershed that received an accumulation of silt. The author found a statistically significantly larger population and higher volume of bottom-dwelling organisms at the control site upstream. After the removal of accumulated sediments and reduction in numbers of organisms due to flooding, the section of stream impacted by sedimentation still produced a slightly but statistically insignificant lower number of organisms than the control section.

Vowell (2001) examined the effects of intensive forest management activities on aquatic habitat in northern Florida using a stream condition index (SCI) based on benthic macroinvertebrate sampling measures. Biological indicators such as this are believed to be more accurate measures of water quality than chemical indicators since the presence, or absence, and abundance of aquatic organisms, benthic macroinvertebrates in particular, better reflect the overall ecological health of water bodies because they integrate pollutant stressors over time. Vowell also evaluated aquatic habitat using an average habitat assessment value based on a composite of physical stream attributes including substrate type and availability, water velocity, artificial channelization, habitat smothering, stream bank stability, riparian buffer width, and riparian buffer quality.

Vowell (2001) found no significant differences between pre- and post-treatment SCI values at any of the four sites, indicating no effect due to silvicultural activities. Average habitat assessment values were also within the optimal range both before and after treatments. The only notable differences found after treatment were changes in the score for water velocity and riparian zone width. The measured increase in water velocity was attributed to minor temporal variability rather than the treatment. Riparian zone widths after harvesting, while considered marginal from a scoring point of view, were still within the required width for primary streams. No change was recorded for habitat smothering or stream bank stability, two components of the habitat assessment considered especially sensitive to impacts from silvicultural activities and critical to maintaining macroinvertebrate population integrity.

Interestingly, some studies have actually documented increases in fish populations and fish size after logging (see Hall and Lantz 1969, Hawkins and others 1983, Murphy and Hall 1981, Murphy and others 1981). These increases are generally attributed to alterations in the food web (National Council for Air and Stream Improvement 1994). For example, increased light penetration or nutrient concentrations may lead to increases in primary productivity that may increase herbivore populations. Slight increases in stream temperature can actually favor fish growth and increase survival of young fish, particularly in northern latitudes or high-elevation streams (Holtby 1988)

Woody Wetlands

Forested wetlands are important for their ability to transform inorganic nutrients into organic form, as well as filter out sediment and particulate matter (Lockaby and others 1997). Forested wetlands were considered unproductive up to the 1950s, when many large pine plantations were established on drained forested wetland sites in the lower Coastal Plain of the South (Xu and others 1999). Forested wetlands are characterized by high seasonal water tables and soil surface waterlogging due to flat topography and poor soil drainage. A brief discussion of the impacts of silvicultural activities on forested wetlands is included below; however, a complete discussion of forested wetland characteristics and potential impacts from various land use activities, including silviculture, is included in chapter 20.

The primary silvicultural activities potentially affecting important wetland functions are site drainage and the operation of heavy equipment on wetland soils, usually during site preparation. Site drainage improves access, provides for soil aeration, and increases seedling survival and growth (Segal and others 1987). Site-preparation practices such as mole-plowing and bedding are among the most prominent silvicultural practices in the South (Xu and others 1999). Mole-plowing uses a deep plow to create a channel in poorly drained soils to improve site drainage. Bedding is a common practice that elevates planted trees on beds above the surface of the water table. Minor drainage is often needed to remove excess surface water to permit heavy equipment to be operated without causing extensive soil compaction and rutting (Shepard 1994).

In contrast to upland forests, surface water flow rates are low in wetlands, which typically have little topographic relief and therefore have less energy available to export sediment. In a review of literature on water quality in forested wetlands, Shepard (1994) found that silvicultural activities generally resulted in water-quality impacts, but the impacts were typically small and short-lived. Impacts were greater in upland wetlands where relief is greater and soils are shallower than in lowland wetland forests. Impacts on all common wetland types have not been investigated. In particular, there is very little published information available on the impacts from bottomland hardwood silviculture on water quality. Shepard (1994) concludes that silvicultural activities "do not constitute a permanent threat to the ability of wetlands to maintain or improve water quality."

Xu and others (1999) examined the effects of clearcutting in the wet and dry seasons and site-preparation activities (bedding and mole-plowing plus bedding) on ground-water levels. The authors found that water tables rose in response to forest removal, with the greatest increases occurring after wet-weather logging. The larger increase associated with wet-weather harvesting was likely due to deeper rutting and greater soil disturbance. No significant differences in ground-water levels were found during the dormant season, indicating that the removal of transpiring vegetation was primarily responsible for the increase in water table levels (Xu and others 1999).

The same study found that site-preparation techniques ameliorated harvest-related elevated water tables by improving site drainage. Bedding reduced ground-water level by up to 22 cm compared to nonbedded sites. Mole-plowing plus bedding had a similar effect on ground-water levels as bedding alone. The recovery of site hydrology was fastest on sites that had been the least disturbed—harvested during dry weather and bedded only. Site hydrology recovered within 2 years of stand establishment (Xu and others 1999).

Miwa and others (1999) also found that wet-weather harvesting had a significantly larger impact on site hydrology than did dry-weather treatment.

Riekerk (1985) conducted a comparative watershed study in the poorly drained pine flatwoods of northern Florida. One watershed was clearcut with minimum disturbance and site preparation (manual shortwood harvesting, slash chopping, soil bedding, and machine planting). The second watershed was clearcut with maximum disturbance and site preparation (machine tree-length harvesting, slash burning, windrowing, soil bedding, and machine planting). The third watershed was an undisturbed control. Runoff increased 2.5-fold on the minimum-treatment watershed and increased 4.2-fold on the maximum-treatment watershed. There was a statistically significant increase in the level of suspended sediment (14 ppm on average) proportional to disturbance, but the absolute levels were low. Significant increases over the control remained for 4 years after both treatments (Riekerk 1985).

Ensign and Mallin (2001) studied the water-quality impacts of clearcutting 130 acres of riparian and seasonally flooded forest in the Coastal Plain of North Carolina. The authors found short-term increases in stream turbidity reaching 111 nephalometric turbidity units (NTU), well above the North Carolina State standard of 50 NTU, but the average increase was not statistically significant. However, compared with an unlogged control stream, suspended sediment concentrations were significantly increased for several months after the clearcut. In addition, statistically significant postlogging increases were reported for both total nitrogen and total phosphorus compared to a nearby control stream.

In aquatic habitats, Ensign and Mallin (2001) found significant decreases in dissolved oxygen that approached anoxia on several occasions after timber harvest. The decreases were attributed to stream algal blooms that formed periodically for two summers after clearcutting. The blooms occurred from a combination of increased nutrient inputs and possibly increased direct solar radiation on surface water. The formation of algal blooms, followed by death and decomposition, created high biochemical oxygen demands leading to decreased dissolved oxygen levels.

Another biotic parameter of interest in streams with human recreation as a designated use is microbial pathogens. Ensign and Mallin (2001) found greatly increased fecal coliform bacterial concentrations in streams following clearcutting. This increase may have occurred due to runoff of pathogens from nearby large-scale swine production facilities, or from the land disturbance itself (Ensign and Mallin 2001).

Lebo and Herrman (1998) examined outflow characteristics in a low-level pocosin with artificial drainage in a 1,161-acre watershed and found that sediment export from the watershed increased nearly 350 percent (4.1 to 14.3 pounds per acre) during a 3-year period that included harvest and site-preparation activities. Minor increases in nitrogen concentrations in streamwater were detected after harvest. These concentrations were typically less than the average value for the control stand. Increases in phosphorus concentrations were more prolonged than for nitrogen, but they decreased to preharvest levels after 3 years.

Management Intensity

This section describes the gradient of potential water-quality impacts across a variety of silvicultural management techniques. The activities discussed include: (1) the harvesting method (single-tree selection, group selection, and clearcutting); (2) the degree of mechanization used in felling and collecting logs (hand felling, feller-bunchers, and cable yarders); and (3) the site-preparation method (windrowing, shearing, disking, prescribed burning, and use of fertilizers and herbicides). Other aspects of timber management associated with management intensity but not related to site disturbance and sedimentation, such as the conversion of hardwood and natural pine stands to pine plantations, are covered in the final section of this chapter. A more thorough discussion of forest operation technologies, including various site-preparation techniques and their impacts on the environment, is included in chapter 15.

In general, as management intensity increases, so does the level of site disturbance. Similarly, the greater the site disturbance, the greater the nonpoint-source impacts, particularly increased erosion and potential for sediment delivery into streams (Riekerk 1985). For example, in the poorly drained pine flatwoods of northern Florida, Riekerk (1985) found increases in total runoff, pH, suspended sediment, and potassium and calcium concentrations proportional to site disturbance in the year after harvest.

Effects of harvest method—It is widely acknowledged that the majority of effects from silvicultural activities can be attributed to operation of heavy machinery on roads and skid trails near water bodies. Rice and Wallis (1962) found no detectable change in stream channel conditions following harvest other than impacts directly resulting from logging equipment and logging debris. Physical alterations included stream channel scouring or filling by bulldozers, slash and debris in channel crossings, and diversion of water down logging roads at stream crossings and road cuts. The diversions caused severe gullying.

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McMinn (1984) compared a skidder logging system and a cable yarder for their relative effects on soil disturbance. With the cable yarder, 99 percent of the soil remained undisturbed (the original litter still covered the mineral soil), while the amount of soil remaining undisturbed after logging by skidder was only 63 percent. Currently, cable yarding is primarily limited to the steepest slopes in the Appalachian Mountains and is otherwise rarely used in the South.

Other studies have demonstrated that the intensity of harvest, depending on the silvicultural prescription, may increase concentrations and loadings of sediment during storms. In watershed research studies in Arkansas and Oklahoma, Scoles and others (1996) found that soil loss increased with harvest intensity (clearcutting versus selection harvesting). Site-preparation activities consisted of crushing and burning residual vegetation. No special erosion control measures were applied. In both studies, statistically significant increases in annual soil loss were found in the first year after clearcutting compared to selectively harvested and control sites. Annual soil losses averaged 211 and 251 pounds per acre on clearcut watersheds in Arkansas and Oklahoma, respectively.

Research conducted by Beasley and Granillo (1985) demonstrated that selective cutting generated lower water yields and sediment yields than did clearcutting. Selective cutting resulted in sediment yields 2.5 to 20 times less and water yields 1.3 to 2.6 times less than those resulting from clearcutting.

Eschner and Larmoyeux (1963) completed a study that compared the water-quality impacts from four harvesting methods: (1) commercial clearcut, (2) intensive selection [trees over 5 inches diameter breast height (d.b.h.) were cut], (3) extensive selection (trees over 11 inches d.b.h. were cut), and (4) diameter limit (trees over 17 inches d.b.h. were cut). However, each of these harvest methods was combined with varying road designs, to determine their overall effectiveness in protecting water quality. It was concluded that the amount of trees removed, or harvesting method, was not the primary factor affecting water quality, as measured by turbidity. Water-quality impacts were shown to be related to the care taken in logging and planning skid roads. The extensive selection method, combined with some nonpoint-source controls (20-percent road grade limits, no skidding in streams, water bars on skid roads), produced higher maximum levels of turbidity than did intensive selection (210 and 25 turbidity units, respectively) with additional control practices (10-percent road grade limits, skid trails located away from streams). Harvesting by diameter limit without any restrictions on road grades or stream restrictions increased maximum turbidity by 200 times over intensive selection (5,200 and 25 turbidity units, respectively). Commercial clearcutting with no controls increased maximum turbidity by over three orders of magnitude compared to harvesting by diameter limit (56,000 and 25 turbidity units, respectively).

Effects of site preparation—Shearing, disking, drum-chopping, or root-raking a site with large tractors may heavily disturb the soil over large areas and has a high potential to deteriorate water quality (Beasley 1979). Site-preparation techniques that remove vegetation and litter cover, compact the soil, expose or disturb the mineral soil, and increase storm-flows due to decreased infiltration and percolation all can contribute to increases in sediment loads (Golden and others 1984). However, erosion rates typically decrease as vegetative cover grows back. Prescribed burning and application of herbicides and fertilizers also have potential negative effects on water quality. These activities are discussed separately in sections that follow.

Shearing, which exposes large amounts of bare soil while removing logging debris, and windrowing resulted in higher levels of soil loss in the Texas Coastal Plain and Athens Plateau (Scoles and others 1996). Shearing also reduced the soil's ability to absorb water in the Texas study. Douglass (1977) found that total soil loss from sites that had been cleared was approximately 580 pounds of soil per inch of runoff. However, runoff from sites that were both cleared and disked was twice that from sites that had been cleared only.

Blackburn and Wood (1990) reported that harvesting and shearing a watershed in east Texas increased phosphate and total phosphorus concentrations in the year after harvest, while harvesting and chopping had no effect on phosphate and total phosphorus concentrations.

As described previously, Xu and others (1999) determined that site-preparation activities (bedding and mole-plowing plus bedding) reduced water table levels significantly in forested wetlands.

Effects of prescribed fire—Prescribed fire can impact water quality by heating the soil and killing soil organisms, thereby altering nutrient transformation rates and bioavailability. These impacts depend on the severity and intensity of the fire. Prescribed burning of slash can increase erosion and sediment delivery to streams by eliminating protective cover and altering soil properties (Megahan 1980). The degree of erosion after a prescribed burn depends on soil erodibility; slope; precipitation timing, volume, and intensity; fire severity; cover remaining on the soil; and speed of revegetation. Swift and others (1993) found erosion after burning to be spotty and did not leave the treated site or reach stream channels. The prescription for this burn, however, was to maintain a low-fire intensity and avoid consuming the compacted litter or organic layers. Burning may also increase stormflow in areas where all vegetation is killed. Such increases are partially attributable to decreased evapotranspiration rates and reduced canopy interception of precipitation. Erosion resulting from prescribed burning is generally less than that resulting from roads and skid trails and from site preparation that causes intense soil disturbance (Golden and others 1984).

Knoepp and Swank (1993) found that clearcutting and burning increased streamwater nitrate concentrations from less than 0.01 mg per L to a maximum of 0.075 mg per L. This small increase was associated with a slight increase in nitrogen transformations and little movement of inorganic nitrogen off the site (Knoepp and Swank 1993). Concentrations returned to pre-treatment levels within 9 months after burning.

In a paired watershed study, Van Lear and others (1985) examined soil and nutrient export in ephemeral streamflow after three low-intensity prescribed fires prior to harvest on the Clemson Experimental Forest in the upper Piedmont of South Carolina. Minor increases in stormflow and nutrient and sediment concentrations in the water were identified after low-intensity prescribed fires. It was suggested that erosion and sedimentation from plowed fire lines accounted for the majority of sediment from all watersheds. Following the prescribed fires, the overstory in the burned watersheds was harvested, and runoff, sediment, and nutrient export were monitored for 3 years after harvest. Sediment levels were elevated after harvest, but the magnitude and duration of these effects were considerably less than from other studies (Douglass and Goodwin 1980, Fox and others 1983, Hewlett 1979) that utilized mechanical site-preparation techniques instead of prescribed burning (Van Lear and others 1985).

Landsberg and Tiedemann (2000) thoroughly reviewed the effects of wildfires and fire management on water quality. The following specific management measures were identified as ways to reduce the magnitude of the effects of fire on water quality: (1) limit fire severity, (2) avoid burning on steep slopes, and (3) limit burning on sandy or water-repellent soils.

Effects of fertilizers, pesticides, and herbicides—Although fertilizer application is uncommon in hardwood forests in the East, forest fertilization is routine—and possibly increasing (Dubois and others 1999)—on many intensively managed pine plantations in the South (Shepard 1994). A brief discussion of the use of fertilizers and pesticides (herbicides and insecticides) in forest operations is included in chapter 15. In a periodic survey of the cost of forest practices, Dubois and others (1999) report that the number of fertilized acres increased between 1996 and 1998. Few studies have looked at the impacts of this practice on water quality (Shepard 1994). Studies typically show that forest fertilization is not a problem; most studies have shown that nutrient increases are too small to degrade water quality (Binkley and Brown 1993, Fisher and Binkley 2000). Many forest streams are nutrient limited, so the application of fertilizers has a greater potential for impacts in nutrient-poor aquatic ecosystems.

Fertilizers, pesticides, and herbicides reach streams either directly through aerial or hand application, or indirectly by surface runoff and subsurface flow. BMPs typically restrict application to nonriparian zones. However, in practice, riparian zones are difficult to avoid in aerial applications. The effects of fertilizer application on aquatic ecosystems are the same as described for nutrients in the section "Aquatic Habitat and Biota."

Pesticides can have both direct and indirect effects on ecological processes. Aquatic organisms can be affected through direct exposure to pesticides in the streamwater or through ingestion. There have been too few studies on the impacts of insecticides to make generalizations about the impacts on fish populations. Some 1- to 2-year studies (Reed 1966) have concluded that short-term reductions in insect populations—an important food source for fish—may occur. Insect communities should recover within a few years due to their short life cycles (National Council for Air and Stream Improvement 1994).

Herbicides can impact aquatic communities directly through increased organic matter inputs and indirectly through other effects on riparian vegetation. These secondary impacts can include changes in physical properties of streams, such as increases in water temperature and sedimentation, due to loss of riparian vegetation. Other secondary impacts to stream properties can result from changes in riparian vegetation, including increased nitrate inputs, decreased slope stability, and altered food-web structure in streams. No critical indirect effects have been documented for normal forest use of herbicides (National Council for Air and Stream Improvement 1994).

In a literature review on forest fertilization with nitrogen and phosphorus and water quality, Binkley and others (1999) found that without the use of BMPs, short-lived elevated nitrate and phosphorus concentrations were often found in receiving waters, but that national drinking water-quality standards (for nitrogen) and/or suggested criteria (for phosphorus) were rarely exceeded. No studies were identified that reported adverse affects on aquatic biota.

The effects of fertilizer application on water quality were studied in three North Carolina plantations (Campbell 1989). Fertilization temporarily elevated levels of ammonium, total nitrogen, total phosphate, orthophosphate, and urea in streams draining plantations. Concentrations returned to pretreatment levels within 3 weeks. Net exports were small compared to the total amount of fertilizer applied: net export of total Kjeldahl nitrogen was 0.3 percent of total nitrogen applied, net export of ammonium was 0.02 percent of total nitrogen applied, and net export of urea was 0.03 percent of total applied urea. Several other studies reported similar results (Fromm 1992, Herrmann and White 1983).

Segal and others (1987) studied the effects on water quality of applying fertilizer and herbicide in a pine flatwood in eastern South Carolina. They identified a strong pulse of nutrient concentrations in July and attributed this to higher mineralization rates of forest floor litter and higher soil temperatures after clearcutting. Nutrient concentrations in ground water did not appear to be outside the range of natural seasonal nutrient dynamics. Furthermore, ground-water quality did not appear to be negatively affected. All nutrient levels returned to pretreatment levels within 200 days after fertilizer application.

Hardwood Conversion to Planted Pine

Swank and Vose (1994) summarized over 40 years of research on changes in water yield and timing of streamflow and over 20 years of stream chemistry data after conversion from hardwood forests to eastern white pine plantations. Significant decreases in water yield (up to 25 percent) were attributed to greater leaf area index throughout the year and, consequently, greater interception loss in the dormant season, plus greater transpiration loss in the early spring and late fall and on warm winter days. The magnitudes of high and low flows were reduced by 33 to 60 percent. Streamwater solute concentrations remained similar on the pine and hardwood watersheds. Net accumulations of calcium, magnesium, potassium, and sodium increased by 1.1 to 3.9 pounds per acre on the pine watershed. Decreases in water yield resulting from extensive hardwood conversion to planted pine could potentially impact the availability of future water yields for municipal water supplies.

In a series of papers on timber harvesting in a Carolina bay, Askew and Williams (Askew and Williams 1984, 1986; Williams and Askew 1988) concluded that pine plantations could be established without harming water quality. Askew and Williams (1984) quantified suspended sediment in drainage waters from active logging sites, site-prepared areas, 3- to 15-year-old plantations, and main ditches in a 2,388-ha Carolina bay in South Carolina. Suspended sediment in new secondary ditches was significantly greater than in native streams draining an undisturbed hardwood stand. Water in the main ditch near the discharge point averaged 16.4 mg per L, compared to 2.5 mg per L in the undisturbed hardwood forest. Ditch contributions to suspended sediment concentrations were transient, culminating within 2 years of installation.

Discussion and Conclusions

The effect of silvicultural activities on water quality is often contentiously debated. Forestry operations have been identified as nonpoint sources of pollution to water bodies draining forest land. Silvicultural activities have the potential to increase sedimentation and alter stream channel conditions (National Council for Air and Stream Improvement 1994). Impacts from these activities are site-specific, varying across the South. Effects depend on elevation, slope, and the rate at which vegetation recovers following harvest. However, in general, if BMPs are properly designed and implemented, the adverse effects of forestry activities on hydrologic response, sediment delivery, stream temperature, dissolved oxygen, and concentrations of nutrients and pesticides can be minimized.

One of the objectives of sustainable forest management is to ensure that silvicultural activities are conducted without significant nonpoint-source pollution of streams and coastal areas. This chapter identified the primary and secondary impacts of silvicultural operations. The following specific management measures should be considered by all forest managers as they develop comprehensive forest management plans. The effectiveness of these management measures to mitigate water-quality impacts is discussed exclusively in chapter 22.

Planning of the timber harvest to ensure water-quality protection will minimize nonpoint-source pollution and increase operational efficiency (Golden and others 1984). Streamside management areas of sufficient width and extent are crucial because they can greatly reduce pollutant delivery. Identification and avoidance of high-hazard areas can greatly reduce the risk of landslides and mass erosion. Careful planning of roads and skid trails will reduce the amount of land disturbed by them, thereby reducing erosion and sedimentation (Rothwell 1978). Proper design of drainage systems and stream crossings can prevent system destruction by storms, thereby preventing severe erosion, sedimentation, and channel scouring (Swift 1984b).

Road system planning is a critical part of preharvest planning. Good road location and design can greatly reduce the sources and transport of sediment. Road systems should generally be designed to minimize the number of road miles per acre, the size and number of landings, the number of skid trail miles, and the number of watercourse crossings, especially in sensitive watersheds. Timing operations to take advantage of favorable seasons or conditions and avoiding wet seasons prone to severe erosion or spawning periods for fish reduce impacts to water quality and aquatic organisms (Hynson and others 1982). Drainage problems can be minimized when locating roads by avoiding clay beds, seeps, springs, concave slopes, ravines, draws, and stream bottoms (Rothwell 1978). Stringer and Thompson (2000) attribute the limited use of topographic maps by loggers and silvicultural operators for many impacts to water quality.

Potential water quality and habitat impacts should also be considered when selecting the silvicultural harvest and yarding systems. It may appear to be beneficial to water quality to use uneven-aged silvicultural systems because they disturb less ground and remove less of the canopy than clearcuts. These factors, however, should be weighed against the possible adverse effects of harvesting more acres selectively to yield equivalent timber volumes. Such harvesting may require more miles of roads and more frequent re-entry into timber stands, which can increase sediment generation. Whichever silvicultural system is selected, preharvest planning should address how harvested areas will be regenerated to prevent erosion and potential impact to water bodies.

Cumulative effects to water quality from forest practices are not well documented (Neary and others 1989, Reid 1993, Vowell 2001). They are related to several processes: onsite mass erosion, onsite surface erosion, pollutant transport and routing, and receiving water effects (Sidle 1989). Cumulative effects are influenced by forest management activities, natural ecosystem processes, and the distribution of other land uses. Timber harvesting, road construction, and chemical use may directly affect onsite delivery of nonpoint-source pollutants as well as contribute to existing cumulative impairments of water quality. The most effective road system results from planning to serve an entire basin, rather than arbitrarily constructing individual roads to serve short-term needs (Swift 1985).

On watersheds where cumulative effects are known to be a problem, the potential for additional water-quality impairments should be taken into account during preharvest planning. Information from previously conducted watershed assessments should be considered. These types of assessments, generally conducted by State or Federal agencies, may indicate water-quality impairments in watersheds of concern caused by types of pollutants unrelated to forestry activities. However, if existing assessments attribute a water-quality problem to the types of pollutants potentially generated by the planned forestry activity, then the problem should be considered during the planning process. If additional contributions to this impairment are likely to occur, planned activities may have to be adjusted or additional mitigation measures may have to be implemented. Alterations may include selection of harvest units with low sedimentation risk, such as flat ridges or broad valleys; postponement of harvesting until existing erosion sources are stabilized; and selection of limited harvest areas using existing roads.

Needs for Additional Research

The nonpoint-source literature is heavily weighted to hydrologic response, sedimentation, and nutrients, the primary silvicultural impacts. Relatively little research has been completed for southern aquatic ecosystems related to channel morphology, dissolved oxygen, pH, woody debris loading, aquatic habitat and biota, hardwood conversion, municipal water supplies, nutrient impacts to lakes, and prescribed fire. Specifically, there is further need to investigate comprehensive biotic impacts from silviculture, including phytoplankton and macroalgal blooms, food-chain impacts, and potential increased microbial pathogen runoff. With predicted increases in intensively managed pine plantations (see chapter 13), additional study is needed of the water-quality effects, e.g., nutrient loading, of increased spraying of fertilizers and pesticides, particularly through aerial applications, in streams and watersheds.

While the available research indicates that individual forestry operations do not contribute significantly to water-quality impairment when BMPs are effectively implemented and monitored, additional research is necessary to assess the long-term cumulative nonpoint-source impacts of silvicultural activities on water quality and overall watershed health. Given the nature of land ownership patterns in the South, this additional research should be conducted by public-private partnerships, with cooperation from forest industry, government agencies, academia, and other interested groups.

The National Council for Air and Stream Improvement (1994) identified the following research needs: (1) development of and testing of more stringent BMPs for some locations; (2) improvement of the capability to effectively evaluate risk; and (3) focus of future research on erosion, sedimentation, and effects on stream channels and fish habitat. Three major areas warrant additional attention: (1) high-nitrate systems; (2) operational-scale assessments of BMP effectiveness (California State Water Resources Control Board 1987, Harvey and others 1988, Knopp and others 1987); and the cumulative effects of management practices within basins.

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Literature Cited

Askew, G.R.; Williams, T.M. 1984. Sediment concentrations from intensively prepared wetland sites. Southern Journal of Applied Forestry. 8: 152–157.

Askew, G.R.; Williams, T.M. 1986. Water quality changes due to site conversion in coastal South Carolina. Southern Journal of Applied Forestry. 10: 134–136.

Beasley, R.S. 1979. Intensive site preparation and sediment losses on steep watersheds in the Gulf Coastal Plain. Soil Science Society of America Journal. 24(2): 61–366.

Beasley, R.S.; Granillo, A.B. 1985. Water yields and sediment losses from chemical and mechanical site preparation in southwest Arkansas. In: Blackmon, B.G., ed. Proceedings of forestry and water quality: a mid-South symposium. Little Rock, AR: University of Arkansas at Monticello: 106–116.

Beasley, R.S.; Granillo, A.B. 1988. Sediment and water yields from managed forests on flat Coastal Plain soils. Water Resources Bulletin. 24(2): 361–366.

Beasley, R.S.; Miller, E.L.; Gough, S.C. 1984. Forest road erosion in the Ouachita Mountains. In: Peters, P.A.; Luchok, J., eds. Proceedings of the mountain logging symposium. Charleston, WV: West Virginia University: 203–212.

Beschta, R.L.; Bilby, R.E.; Brown, G.W. [and others]. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery interactions. Contrib. 57. Seattle: University of Washington, College of Forest Resources: 191–232.

Bethea, J.M. 1985. Perspectives on nonpoint source pollution control: silviculture. In: Proceedings from perspectives on nonpoint source pollution. Washington, DC: U.S. Environmental Protection Agency, Office of Water Regulations and Standards: 13.

Binkley, D.; Brown, T.C. 1993. Forest practices as nonpoint sources of pollution in North America. Water Resources Bulletin. 29(5): 729–740.

Binkley, D.; Burnham, D.H.; Allen, H.L. 1999. Water quality impacts of forest fertilization with nitrogen and phosphorous. Forest Ecology and Management. 121: 191–213.

Blackburn, W.H.; Wood, J.C. 1990. Nutrient export in stormflow following forest harvest and site-preparation in east Texas. Journal of Environmental Quality. 19: 402–408.

Blackburn, W.H; Wood, J.C.; DeHaven, M.G. 1986. Stormflow and sediment losses from site-prepared forestland in east Texas. Water Resources Research. 22(5): 776–784.

Bormann, F.H.; Likens, G.E. 1994. Pattern and process in a forested ecosystem: disturbance, development, and the steady state based on the Hubbard Brook ecosystem study. New York: Springer-Verlag. 253 p.

Bosch, J.M.; Hewlett, J.D. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology. 55: 3–23.

Brown, G.W. 1972. Logging and water quality in the Pacific Northwest. In: Proceedings of the watersheds in transition symposium. Urbana, IL: American Water Resources Association: 330–334.

Brown, G.W. 1985. Controlling nonpoint source pollution from silvicultural operations: what we know and don't know. In: Proceedings of a national conference: perspectives on nonpoint source pollution. Washington, DC: U.S. Environmental Protection Agency: 332–333.

Brown, T.C.; Binkley, D. 1993. Forest practices as nonpoint sources of pollution in North America. Water Resources Bulletin. 29(5): 729–740.

Brown, T.C.; Binkley, D. 1994. Effect of management on water quality in North American forests. Gen. Tech. Rep. RM–248. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 27 p.

California State Water Resources Control Board. 1987. Final report of the forest practices rules assessment team. Sacramento, CA: California State Water Resources Control Board. [Number of pages unknown].

Campbell, R.G. 1989. Water quality mid-year report. Weyerhaeuser Res. and Dev. Rep. New Bern, NC: New Bern Forestry Research Station. [Number of pages unknown].

Chapman, D.W.; McLeod, K.P. 1987. Development of criteria for fine sediment in the Northern Rockies ecoregion. U.S. EPA Water Div. Rep. 910/9–87–162. Seattle: U.S. Environmental Protection Agency. [Number of pages unknown].

Clark, G.M.; Mueller, D.K.; Mast, M.A. 2000. Nutrient concentrations and yields in undeveloped basins of the United States. Journal of the American Water Resources Association. 36(4): 849–860.

Curtis, J.G.; Pelren, D.W.; George, D.B. [and others]. 1990. Effectiveness of best management practices in preventing degradation of streams caused by silvicultural activities in Pickett State Forest, Tennessee. Nashville, TN: Tennessee Technological University, Center for the Management, Utilization, and Protection of Water Resources. [Number of pages unknown].

Dils, R.E. 1957. A guide to the Coweeta Hydrologic Laboratory. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 40 p

Dissmeyer, G.E., ed. 2000. Drinking water from forests and grasslands: a synthesis of the scientific literature. Gen. Tech. Rep. SRS–39. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 246 p.

Douglass, J.E. 1977. Site preparation alternatives: quantifying their effects on soil and water resources. In: Proceedings of site preparation workshop. East Raleigh, NC: [U.S. Department of Agriculture, Forest Service]. [Number of pages unknown].

Douglass, J.E.; Goodwin, O.C. 1980. Runoff and soil erosion from forest site preparation practices. In: U.S. forestry and water quality: what course in the 80s? Proceedings of the water pollution control federation seminar. Richmond, VA: [Publisher unknown]: 92–151.

Dubois, M.R.; McNabb, K.; Straka, T.J. 1999. Costs and cost trends for forestry practices in the South. Forest Landowner. 58(2): 3–8.

Ensign, S.H.; Mallin, M.A. 2001. Stream water quality changes following timber harvest in a Coastal Plain swamp forest. Water Research. 35(14): 3381–3390.

Eschner, A.R.; Larmoyeux, J. 1963. Logging and trout: four experimental forest practices and their effect on water quality. Progress in Fish Culture. 25: 59–67.

Everest, F.H.; Beschta, R.L.; Scriverner, J.C. [and others]. 1987. Fine sediment and salmonid production: a paradox. In: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery interactions. Contrib. 57. Seattle: University of Washington, College of Forest Resources: 98–142.

Fisher, R.F.; Binkley, D. 2000. Forest soils. New York: John Wiley. [Number of pages unknown].

Fox, T.R.; Burger, J.A.; Kreh, R.E. 1983. Impact of site preparation on nutrient dynamics and stream water quality on a Piedmont site [Abstract]. In: Agronomy abstracts. Madison, WI: American Society of Agronomy: 207.

Fromm, J.H. 1992. Jones 5 plantation fertilizer runoff monitoring. Weyerhaeuser Res. and Dev. Rep. New Bern, NC: New Bern Forestry Research Station. [Number of pages unknown].

Golden, M.S.; Tuttle, C.L.; Kush, J.S.; Bradley, J.M. 1984. Forestry activities and water quality in Alabama: effects, recommended practices, and an erosion-classified system. Bull. 555. Auburn, AL: Auburn University, Agricultural Experiment Station. [Number of pages unknown].

Hall, J.D.; Brown, G.W.; Lantz, R.L. 1987. The Alsea watershed study: a retrospective. In: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery: interactions. Contrib. 57. Seattle: University of Washington, College of Forest Resources: 399–416.

Hall, J.D.; Lantz, R.L. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. In: Symposium on salmon and trout in streams. H.R. MacMillan lectures in fisheries. Vancouver, BC: University of British Columbia: 355–375.

Harvey, G.; Hess, S.; Jones, L. [and others]. 1988. Final report: forest practices water quality audit—1988. Boise, ID: Idaho Department of Health and Welfare. [Number of pages unknown].

Hawkins, C.P.; Murphy, M.L.; Anderson, N.H.; Wilzbach, M.A. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the Northwestern United States. Canadian Journal of Fisheries and Aquatic Science. 40: 1173–1185.

Helvey, J.D.; Kochenderfer, J.N. 1987. Effects of limestone gravel on selected chemical properties of road runoff and streamflow. Northern Journal of Applied Forestry. 4(1): 23–25.

Herrmann, R.; White, W.M. 1983. Jones 5 plantation fertilizer runoff monitoring. Weyerhaeuser Res. and Dev. Rep. New Bern, NC: New Bern Forestry Research Station. [Number of pages unknown].

Hewlett, J.D. 1961. Soil moisture as a source of base flow from steep mountain watersheds. Stn. Pap. 132. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

Hewlett, J.D. 1979. Forest water quality: an experiment in harvesting and regenerating Piedmont forests. Georgia For. Res. Pap. Athens, GA: University: of Georgia. [Number of pages unknown].

Hewlett, J.D.; Fortson, J.C. 1982. Stream temperature under an inadequate buffer strip in the southeast Piedmont. Water Resources Bulletin. 18: 983–988.

Hewlett, J.D.; Helvey, J.D. 1970. Effects of forest clear-felling on the storm hydrograph. Water Resources Research. 6: 768–782.

Hewlett, J.D.; Hibbert, A.R. 1966. Factors affecting the response of small watersheds to precipitation in humid areas. In: Proceedings of a national science foundation advanced science seminar, international symposium of forest hydrology. New York: Pergamon Press: 275–290.

Hewlett, J.D.; Post, H.E.; Doss, R. 1984. Effect of clear-cut silviculture on dissolved ion export and water yield in the Piedmont. Water Resources Research. 20: 1030–1038.

Hibbert, A.R. 1966. Forest treatment effects on water yield. In: Proceedings of a national science foundation advanced science seminar, international symposium of forest hydrology. New York: Pergamon Press: 527-543.

Holtby, L.B. 1988. The effects of logging on stream temperatures at Carnation Creek. In: Chamberlin, T.W., ed. Proceedings of the workshop: applying 15 years of Carnation Creek results. Nanaimo, BC: Pacific Biological Station: 118–122.

Hynson, J.; Adamus, P.; Tibbetts, S.; Darnell, R. 1982. Handbook for protection of fish and wildlife from construction of farm and forest roads. FWS/OBS–82/18. Washington, DC: U.S. Fish and Wildlife Service. [Number of pages unknown].

Johnson, D.; Lindberg, S. 1992. Atmospheric deposition and nutrient cycling in forest ecosystems. New York: Springer-Verlag. [Number of pages unknown].

Judy, R.D., Jr.; Seeley, P.N.; Murray, T.M. [and others]. 1984. 1982 national fisheries survey. Tech. Rep: initial findings. FSW/OBS–84/06. Washington, DC: U.S. Fish and Wildlife Service. [Number of pages unknown]. Vol. 1.

Knoepp, J.D.; Swank, W.T. 1993. Site preparation burning to improve Southern Appalachian pine-hardwood stands: nitrogen responses in soil, soil water, and streams. Canadian Journal of Forest Resources. 23: 2263–2270.

Knopp, C.M.; Smith, M.E.; Barnes, J. [and others]. 1987. Monitoring effectiveness of best management practices on national forest lands. In: Callaham, R.Z.; DeVries, J.J., eds. Proceedings of the California watershed management conference. Rep. 11. Berkeley, CA: University of California, Wildland Resources Center: 48–54.

Landsberg, J.D.; Tiedemann, A.R. 2000. Fire management. In: Dissmeyer, G.E., ed. Drinking water from forests and grasslands: a synthesis of the scientific literature. Gen. Tech. Rep. SRS–39. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 124–138.

Lebo, M.E.; Herrman, R.B. 1998. Harvest impacts on forest outflow in coastal North Carolina. Journal of Environmental Quality. 27(6): 1382–1395.

Lieberman, J.S.; Hoover, M.D. 1948. The effect of uncontrolled logging on stream turbidity. Water and Sewage Works. July . [Number of pages unknown].

Likens, G.E.; Bormann, F.H.; Johnson, N.M. [and others]. 1970. Effects of clearcutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecological Monographs. 40(1): 23–47.

Lockaby, B.G.; Clawson, R.G.; Flynn, K. [and others]. 1997. Influence of harvesting on biogeochemical exchange in sheetflow and soil processes in a eutrophic floodplain forest. Forest Ecology and Management. 90: 187–194.

Lynch, J.A.; Corbett, E.S. 1990. Evaluation of best management practices for controlling nonpoint source pollution from silvicultural operations. Water Resources Bulletin. 26(1): 41–52.

Lynch, J.A.; Corbett, E.S.; Mussallem, K. 1985. Best management practices for controlling nonpoint source pollution on forested watersheds. Journal of Soil and Water Conservation. 40: 164–167.

Martin, C.W.; Noel, D.S.; Federer, C.A. 1984. Effects of forest clearcutting in New England on stream chemistry. Journal of Environmental Quality. 13: 204–210.

McMinn, J.W. 1984. Soil disturbance by fuelwood harvesting with a conventional ground system and a cable miniyarder in mountain hardwood stands. In: Peters, P.A.; Luchok, J., eds. Proceedings from mountain logging symposium. Charleston, WV: West Virginia University: 93–98.

Megahan, W.F. 1980. Nonpoint source pollution from forestry activities in the Western United States: results of recent research and research needs. In: U.S. forestry and water quality: what course in the 80s? Proceedings of the water pollution control federation seminar. Richmond, VA: [Publisher unknown]: 92–151.

Miller, E.L.; Beasley, R.S.; Lawson, E.R. 1988. Forest harvest and site preparation effects on erosion and sedimentation in the Ouachita Mountains. Journal of Environmental Quality. 17: 219–225.

Miwa, M.; Aust, W.M.; Burger, J.A. [and others]. 1999. Harvesting and site preparation effects on the hydroperiods of wet flat pine plantations. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 293-297.

Mostaghimi, S.; Wynn, T.M.; Frazee, J.W. [and others]. 1999. Effects of forest harvesting best management practices on surface water quality in the Virginia Coastal Plain. Rep. FNC0999. Blacksburg, VA: Virginia Polytechnic Institute and State University, Biological Systems Engineering. [Number of pages unknown].

Murphy, M.L.; Hall, J.D. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Canadian Journal of Fisheries and Aquatic Science. 38: 137–145.

Murphy, M.L.; Hawkins, C.P.; Anderson, N.H. 1981. Effects of canopy modification and accumulated sediment on stream communities. Transactions of the American Fishery Society. 110: 469–478.

National Council for Air and Stream Improvement. 1994. Forests as nonpoint sources of pollution, and effectiveness of best management practices. Tech. Bull. 672. New York: National Council for Air and Stream Improvement. [Number of pages unknown].

National Council for Air and Stream Improvement. 1999. Silviculture and water quality: a quarter century of Clean Water Act progress. Spec. Rep. 99–06. Research Triangle Park, NC: National Council for Air and Stream Improvement. [Number of pages unknown].

Neary, D.G.; Swank, W.T.; Riekerk, H. 1989. An overview of nonpoint source pollution in the Southern United States. In: Hook, Donal D.; Lea, Russ, eds. Proceedings of the symposium: fhe forested wetlands of the Southern United States. Gen. Tech. Rep. SE–50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 1–7.

Patric, J.H. 1976. Soil erosion in the eastern forest. Journal of Forestry. 74: 671–677.

Patric, J.H. 1978. Harvesting effects on soils and water in the eastern hardwood forest. Southern Journal of Applied Forestry. 2(3): 66–73.

Plamondon, A.P.; Gonzalez, A.; Thomassin, Y. 1982. Effects of logging on water quality: comparison between two Quebec sites. In: Canadian hydrologic symposium '82. [Place of publication unknown]: National Research Council Canada, Associate Committee on Hydrology: 16–25.

Reed, R.J. 1966. Some effects of DDT on the ecology of salmon streams in southeastern Alaska. Spec. Sci. Rep. Fisheries 542. Washington, DC: U.S. Fish and Wildlife Service. [Number of pages unknown].

Reid, L.M. 1993. Research and cumulative watershed effects. Gen. Tech. Rep. PSW–GTR–141. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 118 p.

Reid, L.M.; Dunne, T. 1984. Sediment production from forest road surfaces. Water Resources Research. 20: 1753–1761.

Rice, R.M.; Wallis, J.R. 1962. How a logging operation can affect streamflow. Forest Industries. 89(11): 38–40.

Richter, D. 2000. Soil and water effects of modern forest harvest practices in North Carolina. Individual white paper associated with the economic and ecologic impacts associated with wood chip production in North Carolina study. Durham, NC: Duke University, Southern Center for Sustainable Forests. http://www.env.duke.edu/scsf/. [Date accessed: February 5, 2001].

Riekerk, H. 1983. Impacts of silviculture on flatwoods runoff water quality and nutrient budgets. Water Resources Bulletin. 19: 73–79.

Riekerk, H. 1985. Water quality effects of pine flatwoods silviculture. Journal of Soil and Water Conservation. 40(3): 306–309.

Riekerk, H.; Neary, D.G.; Swank, W.T. 1989. The magnitude of upland silvicultural nonpoint source pollution in the South. In: Hook, Donal D.; Lea, Russ, eds. Proceedings of the symposium: the forested wetlands of the Southern United States. Gen. Tech. Rep. SE–50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 8-18.

Rothwell, R.L. 1978. Watershed management guidelines for logging and road construction in Alberta. Infor. Rep. NOR–X–208. Alberta, Canada: Canadian Forestry Service, Northern Forest Research Centre. [Number of pages unknown].

Scoles, S; Anderson, S.; Turton, D.; Miller, E. 1996. Forestry and water quality: a review of watershed research in the Ouachita Mountains. Circ. E–932, water quality series. Stillwater, OK: Oklahoma State University, Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources. 29 p.

Segal, D.S.; Neary, D.G.; Best, G.R.; Michael, J.L. 1987. Effect of ditching, fertilization, and herbicide application on groundwater levels and groundwater quality in a flatwood spodosol. In: Proceedings of the Soil and Crop Science Society of Florida. 107–112. Vol. 46.

Shepard, J.P. 1994. Effects of forest management on surface water quality in wetland forests. Wetlands. 13(1): 18–26.

Sidle, R.C. 1989. Cumulative effects of forest practices on erosion and sedimentation. In: Forestry on the frontier: Proceedings of the 1989 Society of American Foresters. Bethesda, MD: Society of American Foresters: 108–112.

Silsbee, D.; Larson, G. 1982. Water quality of streams in the Great Smoky Mountains National Park. Hydrobiologia. 89: 97–115.

Society of American Foresters. 2000. A review of waterbodies listed as impaired by silvicultural operations. SAF–00–03. Washington, DC: Society of American Foresters. 13 p. In cooperation with: The National Association of State Foresters.

Stickney, P.L.; Swift, L.W., Jr.; Swank, W.T., comps. 1994. Annotated bibliography of publications on watershed management and ecological studies at Coweeta Hydrologic Laboratory, 1934–1994. Gen. Tech. Rep. SE–86. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 115 p.

Stringer, J.; Thompson, A. 2000. Comparison of forestry best management practices. Part 1. Streamside management zones. Forest Landowner. May/June: 22–27.

Sullivan, K.; Duncan, S.H. 1981. Sediment yield from road surfaces in response to truck traffic and rainfall. Weyerhaeuser Tech. Rep. 042–4404–81–04. Centralia, WA: Weyerhaeuser Forestry Research Center. [Number of pages unknown].

Sullivan, K.; Lisle, T.E.; Dolloff, C.A. [and others]. 1987. Stream channels: the link between forests and fishes. In: Salo, E.O.; Cundy, T.W., eds. Streamside management: forestry and fishery interactions. College For. Resour. Contrib. 57. Seattle: University of Washington: 39–97.

Swank, W.T. 1988. Stream chemistry responses to disturbance. In: Swank, W.T.; Crossley, D.A., eds. Forest hydrology and ecology at Coweeta. New York: Springer-Verlag: 339–357.

Swank, W.T.; DeBano, L.F.; Nelson, D. 1989. Effects of timber management practices on soil and water. In: Burns, Russell, tech. comp. The scientific basis for silvicultural and management decisions in the National Forest System. Gen. Tech. Rep. WO–55. Washington, DC: U.S. Department of Agriculture, Forest Service: 79–106.

Swank, W.T.; Douglass, J.E. 1974. Streamflow greatly reduced by converting deciduous hardwood stands to pine. Science. 185: 857–859.

Swank, W.T.; Miner, N.H. 1968. Conversion of hardwood-covered watersheds to white pine reduces water yield. Water Resources Research. 4: 947–954.

Swank, W.T.; Swift, L.W.; Douglass, J.E. 1988. Streamflow changes associated with forest cutting, species conversions, and natural disturbances. In: Swank, W.T.; Crossley, D.A., Jr., eds. Forest hydrology and ecology at Coweeta. New York: Springer Verlag. [Number of pages unknown].

Swank, W.T.; Vose, J.M. 1994. Long-term hydrologic and stream chemistry responses of Southern Appalachian catchments following conversion from mixed hardwoods to white pine. In: Landolt, Ruth, ed. Hydrologie kleiner Einzugsgebiete: Gedenkschrift Hans M. Keller. Beitrage zur Hydrologie der Schweiz 35. Bern, Schweizerische: Schweizerische Gesellschaft fur Hydrologie und Limnologie: 164–172.

Swift, L.W., Jr. 1984a. Gravel and grass surfacing reduces soil loss from mountain roads. Forest Science. 30(3): 657–670.

Swift, L.W., Jr. 1984b. Soil losses from roadbeds and cut and fill slopes in the Southern Appalachian Mountains. Southern Journal of Applied Forestry. 8: 209–216.

Swift, L.W., Jr. 1985. Forest road design to minimize erosion in the Southern Appalachians. In: Blackmon, B.G., ed. Forestry and water quality: a mid-South symposium. Little Rock, AR: University of Arkansas, Cooperative Extension Service: 141–151.

Swift, L.W., Jr. 1988. Forest access roads: design, maintenance, and soil loss. In: Swank, W.T.; Crossley, D.A., Jr., eds. Forest hydrology and ecology at Coweeta. New York: Springer Verlag. [Number of pages unknown].

Swift, L.W., Jr.; Baker, S.E. 1973. Lower water temperatures within a streamside buffer strip. Res. Note SE–193. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Swift, L.W., Jr.; Burns, R.G. 1999. The three Rs of roads: redesign, reconstruction, and restoration. Journal of Forestry. 97(8): 40–44.

Swift, L.W., Jr.; Messer, J.B. 1971. Forest cuttings raise temperatures of small streams in the Southern Appalachians. Journal of Soil and Water Conservation. 26: 111–116.

Swift, L.W., Jr.; Swank, W.T. 1981. Long term responses of streamflow following clearcutting and regrowth. Hydrological Sciences Bulletin. 26: 245–256.

Tebo, L.B., Jr. 1955. Effects of siltation resulting from improper logging on the bottom fauna of a small trout stream in the Southern Appalachians. Progressive Fish-Culturist. 17: 64–70.

Ursic, S.J. 1991. Forestry practices and the water resource of the upper Coastal Plain. Resour. Rep. 6: 93–96. Gainesville, FL: University of Florida, School of Forest Resources and Conservation. [Number of pages unknown].

Ursic, S.J.; Douglass, J.E. 1979. The effects of forestry practices on water resources. In: Proceedings of the W. Kelly Mosley environmental forum. Auburn, AL: Auburn University Press: 33–49.

U.S. Department of Agriculture, Forest Service. 1984. Regional guide for the South. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. [Number of pages unknown].

U.S. Environmental Protection Agency. 1986. Quality criteria for water: 1986. Washington, DC: U.S. Environmental Protection Agency, Office of Water Regulations and Standards. 402 p.

U.S. Environmental Protection Agency. 1990. National water quality inventory: 1988 report to Congress. EPA 440–4–90–003. Washington, DC: U.S. Environmental Protection Agency. 187 p.

U.S. Environmental Protection Agency. 1992. National water quality inventory: 1990 report to Congress. EPA 503/9–92/006. Washington, DC: U.S. Environmental Protection Agency. 174 p.

U.S. Environmental Protection Agency. 1994. National water quality inventory: 1992 report to Congress. EPA 841–R–94–001. Washington, DC: U.S. Environmental Protection Agency. 328 p.

U.S. Environmental Protection Agency. 1996. National water quality inventory: 1994 report to Congress. EPA 841–R–95–005. Washington, DC: U.S. Environmental Protection Agency. 497 p.

U.S. Environmental Protection Agency. 1998. National water quality inventory: 1996 report to Congress. EPA 841–R–97–008. Washington, DC: U.S. Environmental Protection Agency. 521 p.

U.S. Environmental Protection Agency. 2000a. National water quality inventory: 1998 report to Congress. EPA 841–R–00–001. Washington, DC: U.S. Environmental Protection Agency. 413 p.

U.S. Environmental Protection Agency. 2000b. Nutrient criteria: technical guidance manual. EPA–822–B—00–002. Washington, DC: U.S. Environmental Protection Agency. 256 p.

Van Lear, D.H.; Douglass, J.E.; Cox, S.K.; Auspurger, M.K. 1985. Sediment and nutrient export in runoff from burned and harvested pine watersheds in the South Carolina Piedmont. Journal of Environmental Quality. 14(2): 169–174.

Vowell, J.L. 2001. Using stream bioassessment to monitor best management practice effectiveness. Forest Ecology and Management. 143: 237–244.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monogr. 7. Bethesda, MD: American Fisheries Society. 251 p.

Williams, T.M.; Askew, G.R. 1988. Impact of drainage and site conversion of pocosin lands on water quality. In: Hook, D.D., ed. The ecology and management of wetlands: management, use, and value of wetlands. London, UK: Croom Held: 213–218. Vol. 2.

Xu, Y.-J.; Aust, W.M.; Burger, J.A. [and others]. 1999. Recovery of hydroperiod after timber harvesting in a forested wetland. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 282–287.

Yoho, N.S. 1980. Forest management and sediment production in the South—a review. Southern Journal of Applied Forestry. 4: 27–36.

What are the implementation rates and effectiveness of BMPs in the South?

Chapter 22: Best Management Practices in the South

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Key Findings

■ The nonpoint-source pollutant of greatest concern to forest management is sediment, which reaches stream channels primarily through erosion. Rain splash and sheet erosion account for the majority of hillslope erosion.

■ Maintaining channel stability and the hydrologic character of the watershed can control stream channel erosion and maintain the sediment/stream energy relationship.

■ Silviculture Best Management Practices (BMPs) are designed to reduce nonpoint-source pollution and maintain stream channel integrity so that State water-quality standards are met. Where their effectiveness has been evaluated, they have achieved that goal.

■ All States have adopted silviculture BMPs and have trained landowners, loggers, and forestry practitioners.

■ Twelve of 13 Southern States have measured BMP implementation since 1990, but have employed unique approaches to selecting sample sites and conducting onsite evaluations, resulting in different degrees of statistical strength and different expressions of results. Consistency among States is improving.

■ Six of the 13 States have adapted their BMP implementation monitoring program to incorporate procedures contained in the voluntary regional protocol for implementation monitoring endorsed by the Southern Group of State Foresters in 1997. To date, five States have reported findings based on this approach.

■ The most recent results of statewide BMP monitoring in the five States that utilize common monitoring and reporting methodologies ranged from 63- to 96-percent implementation of all applicable BMPs.

■ In general, BMP implementation has been reported to be highest on public land, followed in descending order by forest industry land, corporate nonindustrial land, and private nonindustrial land.

■ Several States report that forest management operations that involve advice and oversight by forestry professionals exhibit higher degrees of BMP implementation than those not having that involvement. Response by State forestry agencies to BMP violations or complaints varies widely. Six follow established, formal interagency agreements that can include referral to enforcement agencies; seven have no formal process for followup or referral, but do refer some cases to other agencies. All attempt to work with landowners to correct deficiencies prior to referral to enforcement agencies.

■ The Sustainable Forestry Initiative (SFI) of the American Forest and Paper Association requires that member companies adhere to BMPs on company land. In addition, some forest products companies impose sanctions on timber producers who fail to implement BMPs when logging on other ownerships.

Introduction

Best Management Practices (BMPs) are the cornerstone of the forestry community's approach to protecting water resources during and after forest treatments, commonly referred to as management activities. Design and testing of effective BMPs requires an understanding of basic watershed functions, erosion and sedimentation processes, and interactions between these processes and aquatic resources. Implementation of effective BMPs, once designed, requires continuous education of an ever-changing population of forestry practitioners and landowners. Measuring the success of BMP programs requires regular and credible surveying of BMP implementation. This chapter addresses each of these topics independently.

Methods and Data Sources

Scientific literature provided information on erosion and sedimentation processes, BMP effectiveness, and other BMP benefits. The 13 Southern State forestry agencies provided descriptions and results of BMP implementation monitoring in their States as well as information on formal agreements between State agencies for handling suspected incidents of water pollution from forestry operations.

Results

Information on erosion and sedimentation processes and control, BMP effectiveness, and overall benefits of BMPs is presented in narrative form. BMP implementation monitoring information is reported for each State in narrative form and in table 22.1. Due to differences in methods for measuring BMP implementation, comparisons of rates among States are not made. For similar reasons the degrees of implementation achieved by regulatory versus nonregulatory programs are not compared.

Discussion and Conclusions

Erosion and Sedimentation Processes

Sedimentation of surface water is the most common nonpoint-source pollution concern related to forest management activities. Sedimentation is the end result of several processes, including erosion; sediment production, transport and deposition; and instream morphological processes. In-depth discussion of these processes can be found in Dunne and Leopold (1978), Leopold and others (1992), Knighton (1993), and Rosgen (1996). This chapter summarizes portions of those authors' work to provide background and context for the origin, purpose, and design of BMPs.

Hillslope erosion—Erosion is the wearing away of the Earth's surface by wind, water, ice, or gravity. For purposes of this chapter, sediment is the mineral or organic material that is displaced by these forces and delivered to water bodies. Sedimentation is the settlement or deposition of sediment out of the water column.

Table 22.1—Best management practice implementation monitoring program characteristics of 13 Southern States

State	BMP implem. surveys	Implem. rate[a]	Latest survey report	Formal interagency State agreem't.	Ownership classes reported	Identified BMP implem. needs	Comments
	No.	*Percent*					
AL	6	93	N/A	Yes	N/A	N/A	BMP implem. is determined by aerial survey. BMP implem. surveys are conducted, but there are no published reports as such.
AR	2	80	1999	Yes	F, FI, S, NIPF	Roads and harvesting	Southern BMP monitoring recommendations incorporated.
FL	10	96	1999	No	P, FI, NIPF	Roads and trails, and stream crossings	Risk to water quality is evaluated. Southern BMP monitoring recommendations incorporated.
GA	3	BMPs 79, assessed acres 98	1998	Yes	FI, P, NIPF	Stream crossings	Risk to water quality is evaluated. Southern BMP monitoring recommendations incorporated.
KY	1	35 were effective	N/A	No	P, FI, NIPF	N/A	BMPs made mandatory in July 2001. A BMP implem. survey was conducted, but there is no published survey report as such.
LA	4	83 qualitative, 93 quantitative	1997	No	FI, CNIF, P, NIPF	SMZs and permanent roads	As professional assistance increased, BMP implem. increased.
MS	1	87	N/A	No	N/A	N/A	A BMP imple. survey was conducted, but there is no published survey report as such. New BMP monitoring strategy is being developed.
NC	2	95	1996	Yes	P, FI, NIPF	Permanent roads, water bars on temp. roads and skid trails, and SMZ encroachment	As professional assistance increased, BMP implem. increased. Southern BMP monitoring recommendations incorporated.

continued

Table 22.1—Best management practice implementation monitoring program characteristics of 13 Southern States (continued)

State	BMP implem. surveys	Implem. rate[a]	Latest survey report	Formal interagency State agreem't.	Ownership classes reported	Identified BMP implem. needs	Comments
	No.	*Percent*					
OK	0	N/A	N/A	No	N/A	N/A	BMP monitoring program being developed.
SC	5	91.5 harvesting BMPs, 98 site prep BMPs	1997	Yes	P, FI, NIPF	Harvesting systems, SMZs and stream crossings	Risk to water quality is evaluated. Courtesy exam believed effective.
TN	2	63	1996	Yes	N/A	Stream crossings, SMZ encroachment, revegetation of disturbed areas, logging debris in streams	Risk to water quality is evaluated. Southern BMP monitoring recommendations incorporated.
TX	4	89	1999	No	F, FI, NIPF	Stream crossings, temp. roads, and skid trails	Risk to water quality is evaluated. BMP implem. increased with professional assistance, logger and landowner training, and BMP inclusion in the logging contracts. Southern BMP monitoring recommendations incorporated.
VA	10	90 partial imple., 7 full imple.	1999	No	N/A	Water control structures and vegetative cover of disturbed mineral soil	Risk to water quality is evaluated.

N/A = not applicable, F = Federal, FI = forest industry, S = State, P = private, CNIF = corporate nonindustrial, NIPF = nonindustrial private forest owners.
[a] Latest reported overall statewide.

Erosion and sedimentation are natural processes critical to developing and maintaining stream channel form and function. However, sedimentation at above geologic rates, especially fine inorganic sediment particles, can be of concern (Waters 1995).

Rain splash, sheetwash, rills, and gullies associated with overland runoff account for most hillslope erosion. Other sources include mass wasting and soil creep (Dunne and Leopold 1978). Mass wasting usually occurs on steep slopes that slide, or slump, when saturated soils weaken to the point of failing to hold in place against gravity. Soil creep occurs on more gentle slopes where soil particles move downslope very slowly. While these are naturally occurring processes, human activities can cause or accelerate them.

Rain splash erosion occurs when raindrops impact and displace exposed soil. Vegetation and litter cover on the ground absorb virtually all the kinetic energy of rainfall and prevent most rain splash erosion. Thus, protection of soil cover is an important strategy for minimizing this type of erosion.

Sheet erosion occurs when overland flow travels downslope in an irregular, sheetlike fashion. This type of erosion actually occurs as tiny streams of water moving back and forth across the slope. It can transport already detached sediment as well as dislodge soil particles. Several site characteristics including soil particle size and pore space, bulk density, and organic matter content affect sheet erosion processes by influencing soil infiltration capacity. The latter three can be directly affected by management activities.

Rill erosion occurs when sheet flow cuts small, separate channels as it moves downslope. Gullies are rills greater than 1 foot wide and 1 foot deep. Exposed soil in rills and gullies is especially vulnerable to rain splash erosion, so rills and gullies can grow rapidly. Gully erosion can be dramatic, contributing large sediment loads to streams. Nevertheless, rain splash and sheet erosion generally account for over 70 percent of total hillslope erosion (Leopold and others 1995).

Stream channel erosion processes—Channel erosion can be caused by a variety of factors. Most stream channel erosion is caused by the action of instream water (Leopold and others 1995). Water in motion exerts fluid stress, or applied stress, on the streambed and varies with velocity. When applied stress reaches the point that bed particles begin to move, channel erosion results.

The capacity of a stream to carry sediment also increases with stream velocity. At a given flow, velocity varies within channels longitudinally and in cross section. Thus, channel erosion and sedimentation occur simultaneously. The magnitude of these processes is affected by flow rate; high flows increase channel erosion, and low flows increase sedimentation, or deposition.

Rosgen (1996) discusses stream morphology in terms of channel balance, or equilibrium. Sediment size and load vary with stream discharge and stream channel slope, and all exist in a state of dynamic equilibrium. Changes in one variable lead to adjustments by one or more of the others. For example, when sediment delivery to a channel exceeds its transport capacity, sedimentation results. Conversely, reductions in sediment supply below a minimum limit deprive streamflow of sediment, and channels can erode.

Hydrologic responses—Stream equilibrium is also sensitive to hydrologic response of watersheds, especially peak flow. The most important peak flows for channel formation are associated with bank-full events. Bank-full recurs about every 1.5 years, on average. During bank-full floods, streambed material is mobile and channels experience change.

Factors affecting peak flow include the area of impervious material, soil infiltration capacity, time of concentration, drainage density, and antecedent soil moisture. Changes in any of these factors can alter peak flows.

Channel alteration—Channel straightening effectively reduces total channel length over a given elevation change, resulting in increased stream channel slope. Increases in slope frequently increase stream velocity and can cause upstream channel erosion. The effect proceeds upstream until stream slope equilibrium is re-attained.

Constrictions at stream crossings (culverts, bridges) can increase downstream velocity (result in downstream channel scour) and decrease upstream velocity (increase sedimentation above the crossing).

Silviculture BMPs are designed to eliminate or mitigate impacts of management activities on these erosion and sedimentation processes. Natural watershed processes and flow regimes are encouraged and impacts to water quality are minimized by protecting soil cover and soil properties, minimizing channel disturbance, providing adequate road drainage to the forest floor, and designing and properly installing stream crossings.

Other Benefits of BMPs

The origin of BMPs lies in the Federal Water Pollution Control Act (33 U.S.C. 1251 et seq), commonly referred to as the Clean Water Act (CWA). It directs States to develop programs to control nonpoint-source water pollution and to improve quality of water affected by such pollution. It directs States to identify BMPs and other measures to reduce nonpoint-source pollution loadings, and to identify programs for BMP implementation. This law is addressed in more detail in chapters 8 and 19.

Other benefits of BMPs to landowners and the public can be significant. They include improved water quality and aquatic habitat, protected site productivity, and more stable watershed yields. Streamside management zones (SMZs), for example, protect water quality, but also provide habitat for riparian-dependent species, wildlife travel corridors, sources for large woody debris to maintain stream stability and aquatic diversity, and aesthetic benefits. While these benefits exist and can be significant, the exact nature and degree of benefit depend heavily on specific site conditions and circumstances. These variables make it impractical to explicitly address ancillary BMP benefits in this chapter, other than to recognize their relevance and need for further study.

BMPs in this chapter, then, are those designed to protect the chemical, physical, and biological aspects of water quality, and their effectiveness is evaluated in this context.

Effectiveness of BMPs in Protecting Water Quality

Silvicultural activities include final timber harvest, intermediate harvests, site preparation, planting, fertilizer application, pest management, road construction and reconstruction, and fire management. Most, but not all, of these activities involve some degree of ground disturbance.

Aquatic conditions most likely to be impacted by forest treatments include water temperature, sediment and nutrient concentrations, stream channel stability, aquatic habitat quality, and toxic contamination. The purpose of silviculture BMPs is to eliminate or mitigate these effects.

Although States report that silviculture is a relatively minor contributor to stream impairment regionally, the pollutant most often associated with silviculture in State section 305(b) reports is sediment (see chapter 19). Forest roads are the greatest source of forestry-related sediment (Waters 1995, chapter 21). Thus, BMPs commonly focus on eliminating or mitigating sediment from forest roads.

Some of the relevant research and operational monitoring conducted in the South are reviewed in the next sections. Some of the cited studies are highly data intensive from instrumented watersheds, while others are less data intensive, employing upstream versus downstream observations of specified parameters. Both study types, if carefully designed and implemented, yield valuable information from which valid conclusions can be drawn.

Early research—BMPs are based on either research results, where available, or scientific principles. USDA Forest Service scientists at the Coweeta Hydrologic Research Laboratory conducted much of the research that formed the basis for BMPs in the South. Coweeta was established by the USDA Forest Service in the Appalachian Mountains of southwestern North Carolina to describe and understand the physical and biological processes that influence water as it moves through forested watersheds. Coweeta studies were and are data intensive.

Coweeta scientists conducted one of the earliest evaluations of effects of practical forest treatments on water quality in 1956 and 1957. A logging operation was conducted in the Stamp Creek drainage of the Tallulah Ranger District on the Chattahoochee National Forest (Black and Clark, no date). Specific operational standards (forerunners of BMPs) were written into the logging contract to test and demonstrate their ability to protect water quality during commercial logging.

Logging practices and road management were designed to control runoff to the adjacent streams. Roads and landings were located away from streams; storm runoff was removed from roads and dispersed onto the forest floor via strategically located broad-based dips; roads were constructed on the contour and limited to less than 10-percent grade; road crossings of streams were minimized and culverts or bridges installed; and road approaches to streams were graveled. Trees were felled downhill and limbed and topped in place; trees were skidded tree-length uphill by cable, butt-end first; skidding was dispersed over the harvest site; and logging slash was left in place except in streams. After the sale, roads and trails were smoothed of ruts and channels, and broad-based dips were restored and maintained to divert road drainage onto the forest floor.

Sediment concentrations in Stamp Creek, monitored throughout the harvest period, averaged 5 parts per million (ppm) as compared to 4 ppm for a nearby control watershed, and 31 ppm for a watershed logged without the applied operational standards. This was one of the first demonstrations that carefully planned and executed commercial logging practices do not degrade water quality. It also demonstrated that water quality can be impacted if protection is not provided.

Other research at Coweeta demonstrated road design considerations that reduce sedimentation from forest roads (Swift 1984). In one study, two sections of an existing logging access road were reconstructed to standards designed at Coweeta. The design called for an outsloped road with no inside ditches, and broad-based dips to divert road drainage. Grades above broad-based dips were kept constant at between 5 and 7 percent, outlets from broad-based dips were directed to undisturbed forest floor, outside berms kept road drainage off fillslopes, and brush barriers were constructed at the toes of fillslopes. Several key observations resulted from this study.

- Soil loss from roadbeds was greatest during winter storms and peak logging truck traffic.
- Lower road grades had lower soil losses.
- Cut-slope erosion was reduced if debris was left undisturbed at the toe of the slope during road maintenance.
- Outsloped roads without inside ditches reduced cut-slope erosion on many light-duty roads.
- Shorter fills, greater compaction, and brush barriers at fillslope toes reduced fillslope erosion.
- Locating fills away from streams reduced direct sediment input from roads to streams.
- Gravel spread on roadbeds and grass cover on slopes minimized soil losses.
- Grass cover on cut slopes reduced winter cut-slope erosion.
- Grass cover reduced downslope movement of slumps on moistened fillslopes.
- Gravel cover reduced roadbed rutting and erosion in wet seasons.
- Minimizing road width and curve radius reduced road erosion.

In other research, Swift (1986) tested a number of regionally recommended stream buffer widths and an array of other road BMPs for sediment reduction effectiveness. His findings were:

- Grassed fillslopes reduced sediment travel distance to half of that below mulched only and bare slopes.
- Undisturbed forest floor reduced sediment travel distance to half that on a forest floor with litter consumed by prescribed fire.
- Sediment travel distance below forest roads was related to forest floor slope.
- Sediment travel distance from outsloped roads with broad-based dips was not as great as that discharged via culverts.
- Grassed fillslopes and forest floor roughness reduced sediment travel distance by more than 20 feet below forest roads, and brush barriers reduced it more.
- The presence of brush barriers essentially removed the percent slope relationship for sediment travel distance from grassed and ungrassed roadways.
- Ninety-four percent of the soil deposition distances were less than stream buffer widths recommended by the USDA Forest Service Appalachian Guide standards of 1973 for "slight erosion hazard" soils. Thus, the buffer widths were largely adequate.
- A combination of tested practices can be used to reduce the width of required buffer strips for control of sediment from roads.

Swift recommended that filter strip widths between roads and streams in the Appalachians be based on site conditions and construction and stabilization factors such as grassing slopes, out-sloping roads, broad-based dips, cross drains, brush barriers, and forest floor cover.

Examination of State BMPs reveals strong similarities to the previously mentioned practices that were tested at Coweeta. Indeed, this research has been widely used as the scientific basis for BMPs in Southern States. It also demonstrates that BMPs complement one another when employed as a system of practices.

Operational effectiveness monitoring—Several studies have been conducted in the South to test the effectiveness of State BMPs or national forest water-quality standards and guidelines. A variety of water-quality parameters has been evaluated in a variety of locations, testing the effectiveness of differing practices. All provide valuable insight into the topic and several are summarized in the following paragraphs.

Clinginpeel (1989) and Neihardt (1992) measured the effectiveness of BMPs on the Ouachita National Forest in Arkansas and Oklahoma. Clinginpeel focused on BMPs for streamside management areas (SMAs) and for road crossings at streams; Neihardt evaluated BMPs for temporary road crossings of intermittent and ephemeral streams. The measured parameters in both studies were sediment, turbidity in Jackson turbidity units (JTUs), conductivity, alkalinity, pH, nitrites, nitrates, sulfates, and chlorides. Additional parameters in Neihardt's study were total dissolved solids, hardness, turbidity in nephelometric turbidity units (NTUs), acid, and several metals.

Clinginpeel found that sulfates differed significantly above and below stream crossings, but actual differences were small (1.84 mg per liter and 1.94 mg per liter, respectively). Above and below measurements at SMAs were statistically different for turbidity (16.1 and 19.5 JTUs, respectively) and pH (6.13 and 6.32 pH, respectively), but remained within State standards. All the other parameters were unchanged. Neihardt found that turbidity measured in JTUs was statistically different, but turbidity measured in NTUs was not.

Both investigators concluded that forestry BMPs, as implemented on the Ouachita National Forest, effectively maintained water quality within State standards.

In a separate monitoring effort, Clinginpeel (1993) evaluated the effectiveness of BMPs for silvicultural herbicide application on the Ouachita National Forest from fiscal years 1989 through 1993. Again, stormwater samples were collected above and below treated areas from streams in potentially impacted areas, and analyzed for positive readings of Garlon, Velpar, and Roundup. In all, 348 water samples were collected from 168 sites. Sixty-nine samples, or 19.8 percent, tested positive for herbicides, but all positive samples were less than one-fourth the U.S. Environmental Protection Agency (EPA) limit for the specific herbicide and the toxic limit for fish. He concluded that the BMPs tested effectively protected water quality and fisheries.

In the early 1990s the North Carolina Division of Water Quality and the USDA Forest Service examined the effectiveness of BMPs on a forest road in the Appalachians (North Carolina Division of Water Quality 1994). A long-existing road, which closely paralleled Timbered Branch and its tributaries for about 2 miles and had been a chronic source of road sediments to the stream, was retrofitted with a number of measures designed to reduce sediment loading. They included ditch outlets, sediment traps, berms, weeps, outslopes, humps, and relief culverts. Sediment reduction was assessed qualitatively, and biological monitoring was conducted on the affected streams to determine effects on aquatic species. Improvements in taxa richness and diversity in the aquatic community were attributed to the sediment reduction practices.

AQUATIC

The Georgia Forestry Commission, under a CWA section 319 grant and with quality assurance and quality control provided by the Georgia Environmental Protection Division, monitored 1-year-old harvested sites in all physiographic regions of that State and tested for State turbidity standard violations (Green 1995). Selected sites were 90 to 100 percent compliant with forestry BMPs, and all included timber harvests and road construction. Turbidity measurements in NTUs were taken upstream and downstream monthly and immediately after runoff-generating storm events. Neither violations of State turbidity standards nor significant increases in turbidity were found.

The Florida Division of Forestry and the Florida Department of Environmental Protection conducted a biological assessment of four commercially harvested sites before and after harvest (Vowell 2001). Sites selected were on forest industry land and were scheduled for harvest as part of normal ongoing company operations. Management activities at all sites involved clearcut timber harvest, intensive mechanical site preparation, herbicide and fertilizer application, and replanting. Florida's silviculture BMPs were strictly adhered to during all operations. Upstream and downstream habitat and biological assessments were conducted before and immediately after activities were performed, and were continued for 2 years. Investigators found no statistically significant differences in parameters measured between the reference and treated sites. Hence, the authors concluded that Florida's silviculture BMPs were effective in protecting water quality, aquatic habitat, and overall stream ecosystem health.

The South Carolina Forestry Commission, in cooperation with Clemson University and the South Carolina Department of Health and Environmental Control, evaluated the effectiveness of silviculture BMPs in protecting water quality in all physiographic regions in South Carolina (Adams and others 1995). Twenty-seven harvested sites from the Coastal Plain to the mountains were selected. BMP compliance on the sites ranged from inadequate to excellent, thus bracketing the full range of potential effects. BMP effectiveness was determined by Stream Habitat Assessment (SHA) and benthic macroinvertebrate monitoring. Upstream reference sites were used for comparison. Ten sites that rated inadequate for BMP compliance experienced negative SHA impacts, but only one site experienced moderate macroinvertebrate impairment. On sites where BMP compliance was rated as adequate or excellent, SHA indicated that streams were not impacted. The study did not look at an incremental comparison in SHA or bioassessment with incremental BMP compliance. Sites either passed or failed BMP inspection. Sites that passed BMP compliance inspection scored well on the bioassessment. The authors concluded that BMP compliance inspections appeared to be a reliable and economical surrogate for monitoring BMP effectiveness in South Carolina.

Williams and others (1999) evaluated BMP effectiveness in the South Carolina Piedmont, which they considered the most sensitive physiographic province in the State. The authors studied three harvest, site preparation, and regeneration alternatives (with BMPs) for changes in flow, sediment, and nutrients, and compared results to a control watershed. They observed statistically significant increases in observed parameters in all alternatives, but all waters met State water-quality standards. Further, they demonstrated that forestry BMPs reduced sediment yield to one-tenth of that occurring without BMPs.

A report published by the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI 1992), presented numerous documented studies of buffer-strip effectiveness in protecting water quality from silvicultural impacts. It concluded that buffers are effective in reducing transported sediment and pesticides and generally effective in reducing soluble nitrogen and, to a lesser extent, phosphorus delivery to streams.

The above body of scientific literature and monitoring results consistently demonstrates that forest management practices are capable of impacting surface water quality. However, it also demonstrates that appropriate BMPs fully implemented as designed and adapted to the site effectively protect water chemistry, aquatic habitat, and aquatic biota.

BMP Implementation in Southern States

Pursuant to the CWA, each State has developed a State Water Quality Management Plan. These plans include BMPs to reduce nonpoint-source water pollution from various sources, including silviculture. State forestry agencies are typically designated by Governors as the lead agency for silviculture BMP program management. Consequently, beginning in 1978, each Southern State forestry agency, working in cooperation with other forestry experts and their State's water-quality agency, has adopted BMPs. Most have revised their BMPs since 1990.

BMP implementation is largely voluntary in Southern States, but three States (Florida, North Carolina, and Virginia) have linked BMP implementation to other State regulatory programs, making them quasi-regulatory in some circumstances, and BMP implementation became mandatory in Kentucky in July 2000. There are also 15 mandatory Federal BMPs, or conditions, required in all States for exemption of certain silvicultural activities conducted in waters of the United States. See chapter 8 for a more thorough discussion of section 404(f) of the CWA. Compliance with these Federal conditions has not been systematically monitored by any agency.

The voluntary nature of State BMP programs precludes establishing permit conditions. Lacking this mechanism, States have employed logger, forester, forest practice purveyor, and landowner education as the primary tool to achieve BMP implementation. Training has traditionally been conducted in cooperation with forest industries, forestry associations, and State agencies. Member companies of the American Forest and Paper Association are required by the SFI guidelines to meet or exceed State BMPs on company-owned forest land.

To gauge the effectiveness of their educational efforts and to target needed adjustments, State forestry agencies have sponsored or conducted surveys to measure the degree to which BMPs are being implemented. Twelve of 13 States have completed at least 1 survey since 1990. Findings are typically published in formal reports and are available from the respective State forestry agencies. Section 319 (CWA) funding has supported these efforts.

To correctly interpret monitoring results reported by States, it is essential to understand the history of implementation monitoring and how it has evolved. Implementation (compliance) monitoring of non-regulatory BMPs is unique to the forestry community. While other nonpoint-source sectors, such as agriculture, are generally unregulated in the South, the degree of compliance with BMPs for agricultural activities has not been systematically measured or reported. Therefore, survey design standards and monitoring protocols have had to evolve over the 20 years of nonpoint-source program existence. During that time, State forestry agencies have approached implementation monitoring in different ways, degrees of detail, precision, and statistical strength.

Past differences in survey design and statistical strength and metrics chosen for evaluation within and among States preclude precise reporting of State or regional progress over time. Results range from statistically valid to informative but of unknown statistical strength. Statistical approaches are noted in the individual State summaries that follow.

It is important to note that, as with sampling approaches, onsite evaluation of BMP implementation and reporting varies among States. Some provide largely qualitative judgments of overall effort; others calculate and summarize compliance with specific BMPs. These are noted in the State summaries.

States have differed in their aggressiveness toward monitoring BMP implementation, a direct reflection of State priorities and available resources. Seven States have completed more than one comprehensive statewide survey (Florida, 10; Texas, 4; Louisiana, 3; Georgia, 3; Arkansas, 2; North Carolina, 2; and Tennessee, 2). Louisiana is in the process of data analysis and report preparation of its fourth survey. South Carolina has completed four harvesting BMP and two site-preparation BMP surveys. Their current survey system is unique to the region in that it includes three visits to each surveyed site to observe status of BMPs. Alabama has surveyed implementation in differing manners since 1994, but has produced no formal survey report to date. Mississippi and Kentucky have completed one statewide survey, but neither has published a formal report to date. Pursuant to State law, Virginia monitors a percentage of the activities of which it is notified. Oklahoma is planning but has not yet surveyed BMP implementation statewide.

Ten of the States utilize State forestry agency staff to conduct surveys, but university forestry school specialists conducted the surveys in Louisiana and Kentucky. Some States have staff dedicated to water-quality management, but most depend on existing personnel.

Through the 1990s, CWA section 319 funds became readily available to State forestry agencies for BMP program management, and the aggressiveness of implementation monitoring increased. In order to improve regional similarity in survey design and onsite evaluations, the Southern Group of State Foresters (SGSF) recommended in 1997 general forestry BMP implementation monitoring procedures for voluntary use by States. To date, six States (Arkansas, Florida, Georgia, North Carolina, Tennessee, and Texas) have redesigned their programs to incorporate these recommendations.

The SGSF recommends evaluation of specific BMPs in a manner that requires the evaluator to judge whether each applicable practice was implemented properly and completely and whether a risk to water quality exists as a result of noncompliance. Rates are determined by calculating the percent of applicable BMPs fully implemented and are reported by BMP category, such as SMZs, and for the entire operation. The SGSF also recommends sampling treated sites in a systematic and predetermined manner to ensure statistical validity.

The South Carolina monitoring approach has many similarities to the SGSF recommendations, but results are reported differently. While evaluating practices onsite, much of the same data is collected as is called for by the SGSF, but implementation percentages are not reported per BMP category or for the entire operation. Rather, South Carolina reports compliance in a way that reflects the percent of those BMP categories evaluated that were both properly implemented and protected water quality. Sites are also assigned a pass/fail rating based on whether risks to water quality are present.

Other States are either continuing their programs as previously designed or are in various stages of revision to coincide with the SGSF approach.

State implementation monitoring summaries—To compile information contained in the State summaries, written requests were made to each State forestry agency director in March 2000 for BMP implementation monitoring data. Specific information requested included monitoring design, BMP categories measured, implementation rates statewide and by physiographic province, and ownership category if available. Responses were received from all States. As noted earlier, all but one (Oklahoma) reported that they had completed at least one monitoring survey. Following is a brief synopsis of the information received.

Alabama summary—The Alabama Forestry Commission began conducting annual BMP implementation surveys in 1994 (Personal communication. 2000. Timothy C. Boyce, Alabama Forestry Commission. P.O. Box 302550, Montgomery, AL 36130-2550), and monitoring is accomplished by aerial reconnaissance only. BMP survey information is available, although there is no published survey report as such. Until recently the survey was conducted statewide, but currently the survey covers half the State each year, alternating between the north and south. The Commission records all forestry sites via aerial survey, and one site from each county is randomly selected for BMP implementation monitoring every 2 months. Selected sites must be well defined as forestry practices, be 1 year old or less, in any stage of completion (ongoing, stopped, or completed), and free from sampling bias (neither size, ownership, or access are considered). BMP categories are SMZs, stream crossings, forest roads, timber harvesting, reforestation/stand management (includes pesticides and firebreaks), and forested wetland management. The survey evaluation form includes yes or no questions under each BMP category, and at the end of the evaluation, the site is rated yes or no as to whether BMPs were adequately implemented overall. The most recent information is for the survey completed in northern Alabama in fiscal year 1998–99. The survey rated BMP implementation as adequate on 93 percent of sites inspected. Of those with streams present, 80 percent were rated as adequate for SMZs. Alabama does not report by ownership category.

Arkansas summary—The Arkansas Forestry Commission has completed two statewide BMP monitoring surveys; the most recent one was for the survey period 1998–99 (Eagle 1999). Sites were randomly selected, and permission for access was obtained. The number of sites verified was based on sample percentage estimates for projected statistical accuracy of ±5 percent, and was distributed throughout the State on the basis of 1997 timber severance tax records. Sites were harvested from 1 to 24 months before survey, and categories of BMPs were forest road construction and maintenance, harvesting, mechanical site preparation, chemical site preparation, SMZs, and harvest planning. Forest industry provided the Arkansas Forestry Commission with closed-out and site-prepared sites for monitoring. Results are reported statewide and by physiographic region and landowner category.

The overall State BMP implementation rate for the 1998–99 survey was 80 percent. Implementation was 88 percent for planning, 75 percent for roads, 77 percent for harvesting, 79 percent for mechanical site preparation, 80 percent for chemical site preparation, and 81 percent for SMZs.

In the Delta, about 7 percent of all sites were sampled, and the overall compliance rate was 85 percent. About 14 percent of the sites in the Ouachita region were visited; the overall compliance rate was about 77 percent. About 12 percent of the sites were visited in the Ozark region, and overall compliance was about 77 percent. About 67 percent of the sites were visited in the Southwest region; the overall compliance was about 80 percent.

Four landowner categories were recognized in Arkansas. The survey reported 75 percent overall implementation for private nonindustrial landowners, 87 percent for forest industry, 96 percent for national forests, and 82 percent for State land.

Florida summary—The Florida Division of Forestry began biennial silviculture BMP compliance surveys in 1981 (Vowell 2000). The most recent compliance report is for the survey completed in 1999. In all, 199 sites were monitored, the number was that estimated needed to achieve statistical significance at the 95-percent confidence level. Candidate sites must have had silvicultural treatment within the past 2 years and had some part of the site within 300 feet of a stream, lake of at least 2 acres, sinkhole, or wetland identified in the BMP manual. Sites for the survey were distributed across the State based on the level of timber harvest by county, with at least one site for each county that had any harvest activity. Most sites were selected by aerial reconnaissance from aircraft flying over randomly selected township and range lines at an altitude of 800 to 1,200 feet until the target number sites for each county was reached. If flights were not available for any county, sites were selected from the ground, assigned a number, and then drawn by lot.

Florida has 14 BMP categories: SMZs, wetlands, public lands, canals, sinkholes, forest roads, stream crossings, timber harvesting, site preparation, fire line construction, pesticide/fertilizer, waste disposal, wet-weather operations, and emergency conditions. Multiple questions answerable by yes, no, or N/A were evaluated under each category in the survey form, so the total number of actual silviculture practices evaluated on the 199 sites was 4,997. The yes and no answers were tallied, and the percent compliance, exclusive of the N/A answers, was calculated for each site. The survey determined that BMP compliance ranged by category from 91 to 100 percent. The statewide compliance rate was 96 percent in all BMP categories. Of the survey sites, 8 percent were on public land, 37 percent were on industry land, and 55 percent were on private nonindustrial land. Statewide compliance rates for the ownership categories were 99, 97, and 96 percent, respectively.

Included in Florida's BMP survey is the opportunity to note whether significant risk to water quality exists on the evaluated site. The 1997 survey found 0.16 percent of the evaluated practices on all sites monitored posed significant risk to water quality. All of the conditions leading to a significant risk were corrected per the division of forestry recommendations.

Georgia summary—The Georgia Forestry Commission has completed its third BMP implementation survey (Green 2001). The latest survey is the first that conforms to the BMP monitoring protocol endorsed by the SGSF in 1997. The survey was conducted from fall 1997 through summer 1998 on 386 sites selected from across the State in a stratified random sample. All sites experienced some kind of silvicultural treatment in the preceding 2 years, and represented all land ownership categories in all geographic and physiographic provinces. By ownership, 72 percent of the sites were nonindustrial private, 26 percent were forest industry, and 2 percent were public. By physiographic province, about 6.5 percent were in the mountains, 34.5 percent were in the Piedmont, 19 percent were in the upper Coastal Plain, and 40 percent were in the lower Coastal Plain. BMPs were judged as in compliance (yes), not in compliance (no), or not applicable (N/A) under several BMP categories, and a percent compliance was calculated for each category, for the site as a whole and for the State. A judgment was made for each BMP not properly implemented, or found to have failed, as to whether a significant risk to water quality resulted. Results were also expressed in acres, miles of road and streams, and number of stream crossings in full compliance for each BMP category, for the site as a whole, and for the State overall. A total of 6,690 individual BMPs were evaluated over about 43,118 acres.

Percent implementation was calculated in two ways. The number of acres on which BMPs were properly implemented was calculated for each BMP category, and the number of applicable BMPs properly implemented was calculated. Therefore, BMP implementation was reported as a percentage by acres and a percentage by BMP. Categories for BMPs and respective compliance ratings were SMZs (80.9 percent), stream crossings (58.8 percent), main haul roads (76.6 percent), timber harvesting (87.3 percent), mechanical site preparation (96. percent), chemical applications (99.3 percent), control burning (61.5 percent), and artificial regene-ration (93.4 percent). Statewide BMP implementation compliance was estimated at 78.7 percent for all BMP categories in all land ownerships and all physiographic regions. Statewide compliance on the number of acres assessed was 98.2 percent. By land ownership, BMP compliance by acres assessed and BMPs implemented, was 97.4 and 75.4 percent on private nonindustrial, 99.1 and 86.3 percent on forest industry land, and 99.4 and 84 percent on all public land, respectively.

Of particular concern to the Georgia Forestry Commission were stream crossings. However, the commission noted that many of the out-of-compliance stream crossings existed before silvicultural treatments were conducted and were not specifically related to forestry operations. Future surveys will include only treatments specifically related to the forestry activities.

Kentucky summary—The Kentucky Division of Forestry BMP monitoring program estimates BMP effectiveness at mitigating nonpoint-source runoff (Stringer 1997b). The University of Kentucky conducted a BMP survey from September 1995 to April 1997 (Stringer 1997a). The BMP categories monitored included SMZs, roads, trails, landings, and stream crossings.

A total of 100 timber harvest sites were located for systematic sampling from the three physiographic regions of the State. The three regions are area 1 (Jackson Purchase, Western Coal Field, Pennroyal), area 2 (Inner and Outer Bluegrass and the Knobs), and area 3 (Appalachian Plateau and Cumberland Mountains).

Of the 100 sites monitored, evaluators determined that only 80 needed active BMPs. Those 80 were evaluated for BMP implementation.

Monitoring indicated that of those 80 monitored sites, 35 percent had BMPs that were effective, 12.5 percent had BMPs that were partially effective, 10 percent had BMPs that were not effective, and 42.5 percent had no BMPs. In other words, more than half (52.5 percent) of the 80 sites either had no BMPs or the BMPs were ineffective, and less than half (47.5 percent) had BMPs that were effective or partially effective.

Area 2 had the highest incidence of BMPs not used or not effective (59 percent), and area 3 was evenly split (43.2 percent) between "BMPs not used or not effective" and "BMPs effective or active BMP use not needed."

Nonindustrial private land had slightly less implementation and effectiveness of BMPs than the other landowner categories. On a scale of 1 to 5 (1 is worst and 5 is best), public ownerships rated about 4.5 for BMP use and effectiveness, forest industry rated about 3.75 to 4, and nonindustrial private land ownership rated about 3.

Louisiana summary—The Louisiana Department of Agriculture and Forestry has conducted four BMP implementation surveys (1991, 1994, 1997, and 2000). The most recent published report was for the 1997 survey (Hughes and Feduccia 1999), and the 2000 survey was not published in time for inclusion in this Assessment. The number of survey sites necessary to determine with 95-percent confidence if forestry BMP implementation in Louisiana was at least 80 percent in 1997 was estimated at 256; 266 individual sites were actually surveyed. Sample sites were randomly selected by aerial observation, regardless of ownership, and the number of sites in each parish was based on 1996 timber harvest volume. Land ownership categories were forest industry, corporate nonforest industry, nonindustrial private, and public (Federal, State, and local governments). The geographic regions were Delta, northwest, southeast, and southwest.

Categories for BMPs were SMZs, road construction, timber harvest, site preparation and reforestation, and fire line construction. The survey form showed the number of specific BMPs in each category that were assessed. Implementation of BMPs was noted as exceeds, full implementation, minor departure, needed but not applied, and no action required. Exceeds, full implementation, and minor departure were categorized as implemented; needed but not applied was considered not implemented.

Each survey site was given both an overall qualitative and quantitative implementation rating. The qualitative rating was in answer to the yes or no question, "Do you feel there was adequate BMP implementation on this site?" The quantitative rating was calculated as the percentage of implemented BMP guidelines on the site.

The overall statewide qualitative implementation rate was 83 percent, and the statewide quantitative implementation rate was 93 percent. Quantitative geographic implementation rates were 93 percent in the Delta, 94 percent in the northwest, 92 percent in the southeast, and 96 percent in the southwest. Quantitative implementation rates by ownership category were 97 percent for forest industry, 95 percent for corporate nonforest industry, 91 percent for nonindustrial forest, and 93 percent for public. Qualitative rates were not reported for geographic or landowner categories.

Mississippi summary—The Mississippi Forestry Commission conducted a forestry BMP implementation survey in 1994, although there is no published implementation monitoring report (Personal communication. 2000. Michael Sampson, Mississippi Forestry Commission, Suite 3000, 301 Bldg., Jackson, MS 39201). Fifteen tracts harvested during 1993 were randomly selected from among all landowner categories from each of Mississippi's 82 counties, for a total of 1,230 tracts sampled. The survey estimated statewide BMP implementation at 87 percent. The commission recommended corrective measures on the surveyed sites needing BMPs. A new BMP monitoring strategy is being developed.

North Carolina summary—The North Carolina Division of Forest Resources has instituted voluntary BMPs to ensure that the nine mandatory Forest Practice Guidelines (FPGs) related to water quality are met by forest management operations in the State (White 1992). Mandatory FPGs are required for exemption of forestry operations from the Sediment Pollution Control Act passed in the early 1970s. The FPGs are performance standards that must be complied with, while BMPs are the more specific on-the-ground activities that, when applied, should result in maintaining compliance with the FPGs.

The division conducted forestry BMP surveys in 1995 and 1996 (Hensen 1996) and is in the process of completing a 2000 survey. Two hundred timber harvest and 23 site-preparation sites, most of which were harvested between spring 1995 and spring 1996, were selected for the 1996 survey. Tracts had to have potential for affecting some water body, and were randomly selected and distributed throughout the State based on each county's timber production. BMP categories were permanent roads, skid trails and temporary roads, SMZs, landings, and site preparation. Each category had a number of questions to be answered as yes, no, or N/A, and each site received an overall rating of no effort, poor, fair, good, or excellent. Landowner categories were public, industrial, and nonindustrial private. There was no physiographic or geographic stratification in the survey, but there was a slope category broken into three slope ranges: (1) flat (0 to 5 percent), (2) hilly (6 to 25 percent), and (3) steep (less than 25 percent).

Overall statewide BMP implementation was rated at 95 percent as either good or excellent. Public land was rated at 100 percent, industry land at 90 percent, and nonindustrial land at 76 percent. There was no discernable BMP implementation pattern based on slope.

Oklahoma summary—Oklahoma is in the process of conducting its first comprehensive forestry BMP implementation survey. (Personal communication. 2000. Kurt Atkinson, Oklahoma Department of Agriculture, Forestry Services, 2800 N. Lincoln Blvd., Oklahoma City, OK 73105).

South Carolina summary—The South Carolina Forestry Commission conducted BMP compliance surveys for timber harvesting in 1990, 1991, and 1994 (Jones 2000). A site-preparation BMP monitoring survey was conducted in 1996. The BMP monitoring report published in February 2000 presents findings of the harvesting and site-preparation BMP survey begun in 1997.

In 1997, 200 recently harvested sites were located through aerial survey across South Carolina for BMP compliance evaluation. Sites were distributed in proportion to timber harvests in each county relative to the whole State. Three visits were made to each site: one after harvest for compliance with harvest BMPs, one after site preparation for compliance with site-preparation BMPs, and a third visit 2 years after harvest. The final visit examined site stabilization, BMP effectiveness, species and regeneration method used, and any ongoing erosion from silvicultural activities.

BMP implementation is scored in the site evaluations, but the findings are reported in the percent of BMPs determined acceptable for protecting water quality. To be acceptable, no water quality should be measurably impaired by the activity. Harvesting BMP ratings were 98.6 percent acceptable for road systems, 86.7 percent acceptable for road stream crossings, 83.7 percent acceptable for SMZs, and 89.0 percent acceptable for logging systems. Statewide and overall, 91.5 percent of harvesting BMP categories were rated as acceptable.

Site-preparation category ratings were 95.9 percent acceptable for mechanical treatments, 100 percent acceptable for herbicide applications, and 100 percent acceptable for prescribed burning. No sites had minor drainage activities to be evaluated in this survey. Statewide and overall, 98.0 percent of site-preparation BMPs were rated acceptable. Visual observations of ground cover during the second and third visits indicated that naturally occurring vegetation generally stabilized harvested areas after one growing season, even in high-traffic areas and where mechanical site preparation occurred.

Findings by landowner categories were nonindustrial private with under 1,000 acres 87 percent acceptable BMPs, nonindustrial private with over 1,000 acres 94 percent, forest industry 98 percent, and public 100 percent.

There was no physiographic reporting in the 1997 survey, but 11 sites with inadequate harvest system BMPs were noted in the Piedmont and 6 in the Coastal Plain.

Tennessee summary—The Tennessee Forestry Division reported two forestry BMP surveys, one conducted in 1993 and one in 1996 (Tennessee Department of Agriculture Forestry Division 1996). The survey form and protocol were modified in 1995, so results of the two surveys are not entirely comparable. In the second survey, 200 timber harvest and associated road construction sites were evaluated in all physiographic regions. One hundred seventy-nine sites were randomly selected, and 21 sites were investigated in response to water-quality complaints. Monitoring was conducted within 6 months after all activities were completed. Sites selected randomly were not reported separately from those visited due to complaints, so the overall results are not completely unbiased. During the survey, investigators noted instances where water pollution occurred or was likely to occur due to lack of BMPs or improper use of BMPs. In such instances, the operator or landowner was contacted and advised of necessary corrective action.

Examiners noted whether guidelines under each BMP category were implemented or whether the BMP was not applicable to that site. Responses were summed to determine the BMP implementation rates for the forestry practices and the operation as a whole. From the 200 sites evaluated, there was a total of 1,787 individual BMP observations. Ratings for BMP categories were roads 59.5 percent compliance, SMZs 70.5 percent compliance, stream crossings 59.8 percent compliance, timber harvesting 47.6 percent compliance, and waste disposal 87.0 percent compliance. Only one site had been mechanically prepared, and all BMPs were implemented on that site. There were no observations in either the tree planting or fire line construction categories.

The overall statewide BMP compliance rate for the 1996 survey was 62.9 percent for all sites visited, the randomly chosen ones and those visited in response to water-quality complaints. Monitoring results were not broken out by landowner group or physiographic province.

Texas summary—The Texas Forest Service conducted forestry BMP surveys in 1992, 1996, 1998, and 2000 (Carraway and others 2000). Texas revised its survey form and protocol in 1998 to incorporate the protocol of the SGSF.

The most recent survey was conducted between June 1998 and August 1999. A number of yes, no, or N/A assessment questions were evaluated under the various BMP categories. An evaluation of significant risk was added for each assessment question. The purpose was to assess whether failure to properly implement a specific BMP posed significant risk to water quality. The yes and no answers were summed, and an overall site compliance rating was calculated.

One hundred fifty timber harvest sites were randomly selected for investigation by aerial reconnaissance and from knowledge of harvest activities gathered from Texas Forest Service personnel. The sites were distributed among the counties based on estimated annual timber harvest. Sample sites were located without regard to ownership or proximity to water.

Results are reported by BMP category, ownership, and type of operation. BMP categories and overall compliance rates reported were permanent roads 94.1 percent, skid trails/temporary roads 77.5 percent, stream crossings 66.7 percent, SMZs 86.0 percent, site preparation 96.2 percent, landings 98.8 percent, and wetlands, 86.7 percent. Overall State compliance for all categories was 88.6 percent.

Compliance by ownership category was Forest Service 97.9 percent, forest industry 94.2 percent, and nonindustrial private 81.2 percent. Compliance by type of operation was clearcut 85 percent, partial cut 93 percent, thinning 92 percent, and site preparation only 93 percent.

In general, as terrain steepness increased, compliance decreased. Also, the Texas Forest Service reported for the first time a statistically significant increase in BMP compliance when:

- A forester was involved in the timber sale.
- The logging contractor attended the BMP training workshop.
- The landowner was familiar with BMPs.
- There were BMPs in the timber-sale or site-preparation contract.

Virginia summary—Virginia State law requires notification of Virginia Department of Forestry within 3 days of initiating timber harvest (Personal communication. 2000. Samuel Austin, Department of Forestry, Fontaine Research Park, 900 Natural Resources Drive, P.O. Box 3758, Charlottesville, VA 22903-0758). Semiannually, the department randomly selects 30 timber harvests from this database for BMP audits. Monitoring categories are stream crossings, water control structures, seeded areas, SMZs, trail/road grade, rutting, gravel/mats, oil spill/trash, and other. To be in full compliance, 100 percent of applicable BMPs at the audit site have to be 100 percent-implemented and meet 100 percent of the technical specifications of the BMP manual. Measured in this way, compliance has ranged from 16 percent in 1991 to 7 percent in June 1999. Effort to implement BMPs was noted on 90 percent of the sites visited. The field evaluator indicated that 90 percent of the sites were experiencing no related water-quality impacts, but 38 percent exhibited potential for impact.

The above summary of State reports illustrates the variety of BMP monitoring approaches and levels of monitoring effort employed by Southern State forestry agencies over the past 20 years. This reflects the priority placed on BMP implementation monitoring by States, as well as human and financial resource constraints.

The summary also demonstrates the difficulty of discerning actual rates of compliance with specific BMPs. Many on-the-ground determinations of BMP implementation are qualitative by design, adding to the difficulty of comparing or reproducing results. It is also noteworthy that most State surveys are conducted after on-the-ground activities have ceased. Thus, it is possible that water-quality impacts could occur but stabilize prior to the site being evaluated.

Given the nature and limitations of the reported data, three notable characteristics emerge. First, BMPs are being implemented in all States across the South. Rates of implementation reported by five States that use comparable monitoring methodology range from 63 to 96 percent of all applicable BMPs. These States are located throughout the South in a variety of physiographic areas. Second, implementation of BMPs tends to be highest on public land, followed in descending order by forest industry, corporate nonindustrial, and private nonindustrial forest land. Third, forest management operations that involve advice and oversight by forestry professionals exhibit higher BMP implementation rates than operations not having that involvement.

On the whole, the State forestry agencies report increasing BMP implementation over time. They credit this improvement to ongoing efforts to educate those involved in forestry about BMPs and the benefits of BMPs, technical assistance, changing legislation in some States, increasing partnerships with forest industry, and increasing efforts of forest industry (including industry-imposed sanctions on noncomplying timber producers) to improve BMP implementation.

These findings indicate that current approaches to achieving BMP implementation are having positive results, particularly on large ownerships. The challenge remains large and persistent, however, to achieve equal success on nonindustrial private tracts, given that they are owned by almost 5 million individuals (chapters 14 and 16), and a relatively small percentage of these individuals typically receive professional forestry assistance prior to treating their land (chapter 10).

Regulatory Versus Nonregulatory Approaches

Traditionally, water-quality management agencies have depended on regulatory approaches to control point source (discreet conveyance) discharges into State waters. Regulatory processes vary, but typically include establishment of permit conditions, permit application and review, and compliance monitoring. Monitoring is conducted in different ways, ranging from self-monitoring and reporting to site inspections by the regulating agency. This approach provides regulating agencies the opportunity to review plans in advance, encourage or require modifications in order to meet conditions of the regulation, and closely track compliance throughout an activity. Depending on individual statutes, these opportunities might or might not apply to forest management activities if regulatory approaches were to be employed in the South.

As noted, regulatory approaches were developed for and have long been employed to control point-source discharges. Forest management practices are considered nonpoint-pollution sources. The CWA stipulated that nonpoint-source pollution control is to be accomplished through BMPs identified by each State. Though BMP implementation is not mandatory under the CWA, States have the option of developing and implementing regulatory approaches for that purpose.

In all States in the South, BMP programs are administered by State forestry agencies, whose regulatory authorities, with some exceptions, are limited to fire management. Some States require BMP implementation to meet the terms of other State wetlands or sediment control laws or regulations, but none require permit application, review, and issuance prior to forest treatments. Likewise, BMP compliance monitoring is not required.

Several factors have been used to compare and contrast regulatory and nonregulatory approaches to preventing nonpoint pollution from forest management sources. These include cost to landowners, program costs to the State, level of compliance, and degrees of water-quality protection.

Hawks and others (1993) compared Maryland's regulatory with Virginia's nonregulatory program. According to these authors, neither approach was clearly superior to the other in achieving BMP compliance or protecting water quality. Both States were reasonably effective in obtaining BMP implementation. Maryland's regulatory approach was more costly to landowners and to the State.

Another comparison of programs by NCASI (1994) compared and modeled economic and noneconomic costs and benefits of existing and hypothetical regulatory scenarios in Virginia and the State of Washington. The authors concluded that the modeled regulatory program and the most aggressive nonregulatory program scenario would result in nearly equal water-quality benefits. They projected that regulatory program costs would be nearly double those of the nonregulatory program.

Regardless of the approach employed or its actual or perceived advantages, the common goal of both is to achieve protection of water quality. To this end, all Southern States utilize preventive practices (BMPs) and employ followup actions when water-quality degradation is noted or complaints are received. While followup procedures associated with State regulatory programs are not explicitly discussed in this Assessment, formal followup procedures employed by States for forestry BMPs are described here.

Following are State-by-State summaries of current procedures in place to respond to noncompliance or complaints. They are based on information received from State forestry agencies.

Alabama—Alabama has a nonregulatory BMP program (Personal communication. 2000. Timothy C. Boyce, Alabama Forestry Commission. P.O. Box 302550, Montgomery, AL 36130-2550). Through cooperative agreement, the Alabama Division of Environment refers suspected water-quality complaints due to forestry to the forestry commission. A forester visits the area to determine if a forestry-related water-quality problem exists, or could develop, due to lack of or inadequately implemented forestry BMPs. If that situation exists, the responsible party is contacted and provided recommendations for corrective action. A followup visit is made, and if corrective action is not taken, the problem is referred back to the division of environment for appropriate enforcement. The number of BMP complaints acted on by the forestry commission in 1998, 1999, and 2000 were 17, 17, and 42, respectively.

Arkansas—Arkansas has a nonregulatory BMP program (Personal communication. 2000. Dennis M. Eagle, Arkansas Forestry Commission, P.O. Box 10, Greenbrier, AR 72058–0010). The Arkansas Forestry Commission has the lead role for supervising the silvicultural portion of the nonpoint-source water pollution control program. The Arkansas Division of Environmental Quality (DEQ) has regulatory water pollution control authority in Arkansas, and a formal memorandum of understanding exists between the forestry commission and DEQ. Complaints or violations of water quality suspected to be due to forestry are first referred to the forestry commission, which works with the landowner and operator to rectify any identified cause(s) of pollution. If the landowner or operator fails to correct the cause, the incident is referred back to the DEQ, which has authority to institute civil action and assess fines of up to $10,000 per day. The forestry commission estimates acting on about four such complaints or cases per year from 1998 through 2000.

Florida—Florida has a nonregulatory BMP program, but State permits are required for forest roads, stream and wetland crossings, ditching, and borrow pits (Vowell 2000). As part of its BMP monitoring program, the division assesses risk from noncompliance with specific BMPs. When it is determined that a BMP has not been implemented properly, an assessment of "significant risk" is made. Significant risk exists when a situation presents imminent and substantial danger to designated beneficial uses of State waters. In these cases, the division recommends corrective measures to be taken by the landowner. Although no formal memorandum of understanding exists between the division of forestry and the department of environmental protection, if recommended action is not taken, the landowner is referred to the appropriate regulatory authority. This has occurred an estimated six times from 1998 through 2000.

Georgia—Georgia has a nonregulatory forestry BMP program. Incidents of suspected forestry-related water pollution are first referred to the Georgia Forestry Commission, which investigates the site (Personal communication. 2000. Frank Green, Georgia Forestry Commission, P.O. Box 819,Macon, GA 31202-3480). If a water-quality problem is attributable to forest practices, corrective measures are recommended to the operator or landowner. If recommendations are implemented and the problem is corrected, no further action is taken. If the recommendations are not taken and the problem persists, incidents are referred to the Georgia Environmental Protection Division for enforcement action. This has occurred five times between 1998 and 2000.

Additionally, the Georgia Forestry Commission submits a regular report of water-quality violators to the forest industry members of the SFI, who individually can stop accepting wood from those producers at their mills. The SFI mills that receive wood from producers on that list contact those producers and tell them they are at risk of not having their wood accepted at their gates.

Likewise, the State Board of Registered Foresters in Georgia has adopted a system for imposing sanctions against registered professional foresters for BMP noncompliance (Personal communication. 2001. Frank Green, Georgia Forestry Commission, P.O. Box 819, Macon, GA 31202-3480). In cases of BMP noncompliance, registered professional foresters may face penalties including consent agreement, fines, license suspension, license probation, and public reprimand.

Kentucky—Kentucky instituted a new regulatory timber harvesting BMP program on July 15, 2000 (Personal communication. 2000. Larry Lowe, Department of Natural Resources, Division of Forestry, 627 Comanche Trail, Frankfort, KY 40601). Loggers are required to use appropriate BMPs, and a Kentucky Master Logger (a logger who has completed the logger-training program of the Kentucky Division of Forestry) must be on site and in charge of any commercial logging operation. The division visits and inspects logging operations for compliance. Noncompliance results in a written warning to the logger describing what is out of compliance and what needs to be accomplished to bring the operation into compliance. If the written warning fails to bring corrective action, an informal conference is held with the logger. Failing correction, a notice of violation is issued, and, as a last step, a special order is issued. The special order provides for shutting down a portion of the operation until compliance is achieved. Where noncompliance is serious enough to pose a significant threat to water quality, an emergency order can be issued which will shut down the entire operation without going through the first three steps. If these steps for attaining BMP compliance fail, the division of forestry can initiate administrative hearings, fines, or court actions. Prior to this program, the division of forestry reports that they referred several silviculture-related water-quality cases to the division of water, but their exact number and resolution status are unknown.

Louisiana—Louisiana has a nonregulatory BMP program. Louisiana has no formal process in which suspected forestry-related water-pollution cases are handled separately from any other suspected nonpoint-source pollution problem (Personal communication. 2000. Don Feduccia, Louisiana Department of Agriculture and Forestry, Office of Forestry, P.O. Box 1628, Baton Rouge, LA 70821-1628). When the Louisiana Department of Agriculture and Forestry is called out on a site with suspected forestry water-quality violations, it may make suggestions for BMPs that may be missing or inadequate. No formal departmental process exists for dealing with specific forestry operations suspected of causing water pollution, nor does any formal agreement for addressing such occurrences exist between the department of agriculture and forestry and any other State agency.

Mississippi—Mississippi has a nonregulatory forestry BMP program (Personal communication. 2000. Michael Sampson, Mississippi Forestry Commission, Suite 3000, 301 Bldg., Jackson, MS 39201). In cases of BMP noncompliance, the commission makes recommendations to correct the problems. No formal interagency agreement exists for referrals.

North Carolina—North Carolina has a set of mandatory FPGs, which are performance standards specified for various forest management categories, but has voluntary forestry BMPs designed to ensure attainment of the FPGs (White 1992). The North Carolina legislature passed the Sediment Pollution Control Act, which requires a site plan for land-disturbing activities and is enforceable by the division of land resources. The act initially exempted forestry, but in 1989 it was amended to exempt forestry only so long as forestry activities are conducted in accordance with FPGs.

In cases of citizen complaints or other reported incidents of guideline noncompliance, a division of forest resources representative visits the suspected sites and recommends remedial action with a timetable to the operator. If the responsible operator cannot be found, the recommendation is given to the landowner. If recommendations are not implemented and a water-quality problem(s) continues, the incident is referred to the department of land resources, the division of water quality, or the division of forest resources law enforcement staff for action. Activity can be stopped and a fine of $1,000 levied, a sediment plan required within 30 days of disturbance, specific cleanup measures required, and a $500 per day fine levied if cleanup is not accomplished. The site is monitored until cleanup is finished.

Since 1990, over 26,000 guideline evaluations have been conducted, about 1,900 notices of noncompliance have been issued, and approximately

100 cases referred for enforcement to other State agencies (27 since 1998). Cases resolved without the need for punitive action have not been formally tracked.

Oklahoma—Oklahoma has a nonregulatory forestry BMP program (Personal communication. 2000. Kurt Atkinson, Oklahoma Department of Agriculture, Forestry Services, 2800 N. Lincoln Blvd., Oklahoma City, OK 73105). Suspected forestry-related water-quality violations are inspected by forestry services, and any necessary corrective action is recommended. If the operator or landowner does not take the recommended action and a water-quality violation persists, the incident is referred to the DEQ for necessary enforcement action. There is no formal interagency agreement for referrals of this kind. In addition, some major forest industries in Oklahoma accept wood at their gates only from loggers who have completed master logger training, which includes a module on forestry BMPs.

South Carolina—South Carolina has a nonregulatory silviculture BMP program with regulatory backup provided by the South Carolina Department of Health and Environmental Control (DHEC). A formal memorandum of understanding between the South Carolina Forestry Commission (SCFC) and DHEC defines the role of each agency in preventing or correcting water-quality impacts from forestry operations. The DHEC refers all forestry-related water-quality complaints to SCFC for investigation. The forestry commission recommends corrective actions to the landowner and forestry operator, where noted problems can be resolved. Sites on which SCFC recommendations are not implemented within 30 days are referred back to DHEC for enforcement action.

AQUATIC

Additionally, SCFC has developed a Courtesy Exam Program, unique in the Southern States, as a proactive means to encourage proper BMP implementation (Jones 2000). In this program, active forestry operations are located through weekly aerial reconnaissance of major drainages; through voluntary prior notification by foresters, loggers, or site-preparation contractors; through complaints from the public; through the DHEC; and through other sources. Permission is secured from landowners to visit individual sites, the operators are contacted, and BMP foresters inspect the sites for BMP compliance. Written recommendations based on the site visits and BMP manuals are provided to the landowners and contractors, and the BMP foresters make followup visits after project completion to see if BMPs were followed and if related water-quality problems occurred.

Monthly courtesy exam summaries are provided to DHEC and made available to others upon written request. Summaries include a list of operators who failed to implement BMPs and may have created unresolved water-quality problems. Individual forest products companies have used this information to take corrective actions that they deem necessary. Actions have included refusal of wood at the mill, mandatory State monitoring, and additional training requirements (Personal communication. 2001. Tim Adams, South Carolina Forestry Commission, P.O. Box 21707, Columbia, SC 29221). The courtesy exam program is credited for achieving high rates of BMP implementation in South Carolina. In 1999, for example, BMP compliance was 99 percent on sites that underwent a courtesy exam.

Tennessee—Tennessee has a nonregulatory BMP program (Personal communication. 2000. David Arnold, Department of Agriculture, Forestry Division, Box 40627, Nashville, TN 37204). In incidents of suspected water pollution due to forestry, investigators from the department of agriculture are called in to assess the sites and recommend any necessary corrective measures. If, after reasonable efforts by that department, an operator or landowner fails to cooperate or comply with recommendations, the department of environment and conservation may take appropriate enforcement action. During 1998 to 2000, 126 cases were referred by the division of forestry.

The Tennessee State Legislature passed House Bill 2846 in 2000, which gives stop-work authority to the Commissioner of Environment and Conservation. When water pollution occurs because an operator fails to use forestry BMPs, the commissioner, after consultation with the department of agriculture, may issue a stop-work order, and shall at the same time notify the landowner that a stop-work order has been issued. The operator must then cease part of or all activities contributing to the pollution. The order will remain in effect until the operator implements the forestry division's recommended BMPs that eliminate and prevent further pollution from forestry activities at that site. Any operator who receives a stop-work order must, for the next 2 years, notify in writing the Commissioner of Agriculture and the Commissioner of Environment and Conservation at least 10 days prior to beginning any silvicultural activity. Information must include the names of the landowner and operator, the location of and acreage of proposed silvicultural activity, and the beginning and expected ending dates of silvicultural activities.

Texas—Texas has a nonregulatory BMP program (Personal communication. 2000. Burl Carraway, Texas Forest Service, Best Management Practices, P.O. Box 310, Lufkin, TX 75902-0310). There is no formal State interagency agreement by which BMP noncompliance is addressed. However, there is a State coordinating committee consisting of all regulatory agencies (Texas Natural Resources Conservation Council, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency) and the forestry community (Texas Forest Service, Texas Soil and Water Conservation Board, Texas Forestry Association, Texas Loggers Council, forestry consultants, Texas Parks and Wildlife Department, forest industry, and others). In cases of reported or discovered BMP noncompliance, or nonpoint-source water pollution from forestry operations, the coordinating committee provides advice for recommended BMPs and seeks cooperation of the logger and/or landowner. Texas has a "bad actor" provision in its water-quality law that allows pursuit of a repeat offender, but it rarely, if ever, has been used with respect to silviculture. The Texas forest industries that subscribe to the SFI have taken it upon themselves to audit timber producers supplying their mills, and producers found in noncompliance with BMPs are counseled to improve BMP implementation. Those who do not comply with Texas-recommended BMPs are not permitted to deliver wood at these mills. This arrangement is believed to be producing an improving trend in BMP implementation in Texas, but there are many small timber industry mills that do not subscribe to the SFI.

Virginia—Virginia has a non-regulatory BMP program, but it does have mandatory harvest notification no later than 3 working days after the initiation of harvest operations (Personal communication. 2000. Matt Poirot, Department of Forestry, Fontaine Research Park, 900 Natural Resources Drive, P.O. Box 3758, Charlottesville, VA 22903-0758). Further, the Silvicultural Water Quality Law, effective June 1, 1993, authorizes the Virginia Department of Forestry to require corrective measures for silvicultural operations causing, or with potential to cause, sedimentation of State waters. In cases where the department enforces this law, the first step is issuance of a notice of required action, which is an informal description of what needs to be done to correct the problem. If that fails to bring resolution, an informal conference is held with the operator. The next step could be issuance of a special order, which details proof of sediment pollution and contains a step-by-step prescription of necessary corrective measures with a schedule for work. If the operator fails to comply with the special order, a formal hearing is held to determine if the special order was violated. Finally, civil fines of up to $5,000 per day can be assessed. This authority also includes issuance of stop-work orders. Formal actions taken by the department of forestry in 1998, 1999, and 2000 total 199, 272, and 540, respectively. The increase in 2000 is attributed to addition of compliance monitoring staff.

Other forestry-specific State laws include the Chesapeake Bay Preservation Act and local land use tax rules. These acts and rules exempt forestry from certain requirements, or exempt forest land from certain taxes, provided that BMPs are implemented and verified by the department of forests. Monitoring of BMPs for compliance with the Silvicultural Water Quality Law is done coincidentally on about 240 randomly selected tracts per year through quarterly administrative review in the six department regions, and through the semiannual BMP implementation and effectiveness monitoring survey.

Analysis of this topic leads to several broad observations:

- The nonregulatory approach utilized in Southern States over the past 20 years to protect forest water resources is nontraditional, unique, and still evolving. Its dependence on practitioner education, direct landowner assistance, and systematic monitoring of program effectiveness has gained momentum and widespread acceptance in the forestry community.
- The silviculture BMPs recommended by Southern States are grounded in science or are based on scientific principles. While there are differences among States in specific individual BMPs applied on the ground (SMZ widths, for instance), consistency among States is generally strong and continues to increase. While not tested for effectiveness in every State or ecological region, studies conducted to date have found BMPs effective at maintaining State water quality within applicable standards. Additional scientific validation of BMP design will serve to refine their application to fit site-specific conditions.
- Success of the nonregulatory approach requires continual education efforts targeted at the ever-changing groups and individuals who own and treat the South's forests.
- Documenting the effectiveness of these approaches and their efficacy in protecting water resources is complex, costly, and still evolving. Southern States vary widely in their methodologies and commitment of resources for BMP monitoring.

Needs for Additional Research

- Additional documentation of the scientific basis for BMPs and studies of BMP effectiveness are needed to evaluate them in representative ecological provinces in the South. Key topical areas should include stream crossings, SMZ harvesting options, and overall SMZ management. Chemical, physical, and biological water-quality parameters and stream channel stability indices should be documented for different stream types.
- Reasons that landowners comply or do not comply with BMPs are not well understood. Additional information of this kind would be useful for targeting outreach efforts and adjusting State programs.
- Resource benefits provided by BMPs other than water-quality protection should be studied and documented. This information would be useful for encouraging landowner acceptance and could identify needed modifications in BMPs. Landowner understanding of the full range of benefits derived through BMPs, in addition to water quality, may increase landowner commitment to BMPs.
- Effects of nontimber uses of forests, such as off-road vehicle use and equestrian crossings, are not well documented, but are potentially significant. Effects of these uses may be similar to those of roads and skid trails (concentrated traffic in small, potentially high-impact areas). Science-based BMPs could be tailored for these and other common forest uses.
- Economic costs and benefits of BMPs to landowners are not well understood, and should be documented.

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Literature Cited

Adams, T.O.; Hook, D.D.; Floyd, M.A. 1995. Effectiveness monitoring of silvicultural best management practices in South Carolina. Southern Journal of Applied Forestry. 19(4): 170–176.

Bible, Robin P. 1998. Protecting water quality during forestry activities in Tennessee. Land and Water, The Magazine of Natural Resource Management and Restoration. Ft. Dodge, IA: September/October: 6–8.

Black, P.E.; Clark, P.M. [n.d.]. Timber, water, and Stamp Creek. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station and Region 8. 13 p.

Carraway, Burl; Clendenen, Larry; Work, Donna. 2000. Voluntary compliance with forestry best management practices in east Texas. Results from round 4 of BMP compliance monitoring 1998–1999. College Station, TX: Texas Forest Service. 30 p.

Code of Federal Regulations. 2000. 40CFR232.3. Washington, DC: U.S. Government Printing Office: 274–278.

Cook, Michael J.; King, John G. 1983. Construction cost and erosion control effectiveness of filter windrows on fill slopes. Res. Note INT–335. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 5 p.

Dunne, Thomas; Leopold, Luna B. 1978. Water in environmental planning. New York: W.H. Freeman and Co. 818 p.

Eagle, Dennis M. 1999. Arkansas voluntary forestry best management practices implementation report. Results from second survey BMP implementation monitoring, Arkansas Forestry Commission survey period: 1998-99. Little Rock, AR: Arkansas Forestry Commission. 18 p.

Green, Frank. [In press]. Results of 1998 BMPs for forestry in Georgia compliance survey. Macon, GA: Georgia Forestry Commission.

Green, Frank. 1995. The effects of silvicultural practices on water quality in Georgia: a study of turbidity. Macon, GA: Georgia Forestry Commission. 17 p.

Hawks, Laurie J.; Cubbage, Fredrick W.; Haney, Harry L., Jr. [and others]. 1993. Forest water quality protection, a comparison of regulatory and voluntary programs. Journal of Forestry. 91(5): [Number of pages unknown].

Heede, Burchard H.; King, Rudy M. 1990. State of the art timber harvest in an Arizona mixed conifer forest has minimal effect on overland flow and erosion. Hydrological Sciences Journal. [des Sciences Hydrologiques]. 35(6). [Number of pages unknown].

Henson, Mickey. 1996. Best management practices implementation and effectiveness survey on timber operations in North Carolina 1996. Raleigh, NC: North Carolina Division of Forest Resources. 20 p.

Hughes, Melinda S.; Feduccia, Don. 1999. Louisiana's voluntary compliance with forestry best management practices–1997. Baton Rouge, LA: Louisiana State University Agricultural Center, Louisiana Agricultural Experiment Station. 27 p.

Jones, Darryl. 2000. Implementation monitoring of forestry best management practices for harvesting and site preparation in South Carolina 1997–1999. Best Manage. Pract. Monit. Rep. BMP–4. Columbia, SC: South Carolina Forestry Commission. 13 p.

Knighton, David. 1993. Fluvial forms and processes. New York: Routledge, Chapman, and Hall, Inc. 218 p.

Leopold, Luna B.; Wolman, M. Gordon; Miller, John P. 1995. Fluvial processes in geomorphology. Mineola, NY: Dover Publications, Inc. 522 p.

NCASI. 1992. The effectiveness of buffer strips for ameliorating offsite transport of sediment, nutrients, and pesticides from silvicultural operations. NCASI Tech. Bull. 631. New York: National Council of the Paper Industry for Air and Stream Improvement, Inc. 48 p.

NCASI. 1994. Benefits and costs of programs for forestry nonpoint pollution control in Washington and Virginia. NCASI Tech. Bull. 660. New York: National Council of the Paper Industry for Air and Stream Improvement, Inc. 45 p.

North Carolina Division of Water Quality. 1994. Timbered branch demonstration/BMP effectiveness monitoring project. Raleigh, NC: North Carolina Division of Water Quality. 9 p.

Rosgen, D.L. 1996. Applied river morphology. Pagosa Springs, CO: Wildland Hydrology. 352 p.

Stringer, Jeffrey W.; Queary, Tim R. 1997a. Kentucky's timber harvesting BMP implementation study: preliminary results. FORFS 97–4. Lexington, KY: University of Kentucky, College of Agriculture, Cooperative Extension Service. 2 p.

Stringer, Jeffrey W.; Queary, Tim R. 1997b. Outline of Kentucky's timber harvesting BMP implementation survey. FORFS 97–2. Lexington, KY: University of Kentucky, College of Agriculture, Cooperative Extension Service. 2 p.

Swift, Lloyd W., Jr. 1984. Soil losses from roadbeds and cut and fill slopes in the Southern Appalachian Mountains. Southern Journal of Applied Forestry. 8(4): 209–215.

Swift, Lloyd W., Jr. 1986. Filter strip widths for forest roads in the Southern Appalachians. Southern Journal of Applied Forestry. 10(1): 27–34.

Tennessee Department of Agriculture. 1996. 1996 BMP implementation survey report. Nashville, TN: Tennessee Department of Agriculture, Forestry Division. 23 p.

U.S. Department of Agriculture, Forest Service. 1973. Guide for managing the national forests in the Appalachians. FSH 2123. Version 1.3. Atlanta: U.S. Department of Agriculture, Forest Service, Eastern and Southern Regions. 34 p.

U.S. Government Printing Office. 1989. Federal Water Pollution Control Act (33 U.S.C. 1251 et seq). Compilation of selected water resources and water pollution control laws. Washington, DC: U.S. Government Printing Office. 249 p. [Printed for the use of the Committee on Public Works nd Transportation].

Vowell, Jeff ; Gilpin, Tom. 2000. Results of Florida's 1999 silviculture BMP compliance survey. Tallahassee, FL: Florida Department of Agriculture and Consumer Services Division of Forestry. 14 p.

Vowell, Jeffery L. 2001. Using stream bioassessment to monitor best management practice effectiveness. Forest Ecology and Management. 143: 237–244.

Waters, Thomas F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monogr. 7. Bethesda, MD: American Fisheries Society. 251 p.

White, Fred. 1992. History of forest practices guidelines in North Carolina. Raleigh, NC: North Carolina Division of Forest Resources. 7 p.

Williams, T.M.; Hook, D.D.; Limpscomb, D.J. [and others]. 1999. Effectiveness of best management practices to protect water quality in the South Carolina Piedmont. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 271–276.

References

Clinginpeel, J. Alan. 1989. Above and below storm sampling BMP effectiveness; FY 1989 monitoring results. 2 p. Unpublished report. On file with: Ouachita National Forest, Box 1270, Federal Building, Hot Springs, AR 71902.

Clinginpeel, J. Alan. 1993. Herbicide effectiveness monitoring on the Ouachita National Forest for water quality in the fiscal years 1989 through 1993 (a 5-year summary). 22 p. Unpublished report. On file with: Ouachita National Forest, Box 1270, Federal Building, Hot Springs, AR 71902.

Neihardt, Charlene. 1992. BMP effectiveness monitoring using above and below storm sampling. FY 1992. 2 p. Unpublished report. On file with: Ouachita National Forest, Box 1270, Federal Building, Hot Springs, AR 71902.

Personal communication. 2001. Kurt Atkinson, Oklahoma Department of Agriculture, Forestry Services, 2800 N. Lincoln Blvd., Oklahoma City, OK 73105.

Personal communication. 2000. Jim Bowen, Virginia Department of Forestry, P.O. Box 3758, Charlottesville, VA 22903.

Personal communication. 2000. Richard Burns, National Forests in North Carolina, 160a Zillicoa Street, P.O. Box 2750, Asheville, NC 28802.

Personal communication. 2000. Mark Matuszewski, Department of Natural Resources, Division of Forestry, 627 Comanche Trail, Frankfort, KY 40601.

What are the history, status, and likely future of aquatic habitats and species in the South?

Chapter 23: Aquatic Animals and their Habitats

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Key Findings

■ Sediments, introduced into aquatic systems above natural, background levels, have adverse impacts on animal species in all seven taxonomic groups considered in this Assessment.

■ The aquatic communities of Southeastern United States are globally significant. Many are very narrow endemics and subject to extinction from relatively minor habitat losses.

■ Habitat barriers created by dams on major rivers have produced isolated populations of many southern aquatic animals. Some species occupy so little of their former range that they are vulnerable to extinction as described for the narrowly endemic species. Some others, mainly larger river animals, have become extinct because of habitat alterations. Current programs have improved conditions in some of the tailwaters.

■ In some areas aquatic habitats have improved, and reintroduction or augmentation supported by captive breeding programs may improve the recovery potential for some species.

■ Some ground-water systems are being dewatered, threatening unique aquatic communities. Careful aquifer management will be necessary for these aquatic communities.

■ Certain aquatic species, for example, the flatwoods salamander, require ephemeral ponds to complete their life cycles. Restoration and protection of ephemeral ponds is essential to the conservation of these animals.

■ Gaps in our scientific knowledge about southern aquatic species are monumental. Research of many types is urgently needed.

■ In the South, much of the habitat for rare aquatic species is not controlled by Federal or State governments. The burden for protecting these habitats falls mainly on private landowners.

Introduction

Master and others (1998) ranked the United States as first in terms of diversity of known aquatic species worldwide. Native taxa include crayfish, freshwater mussels, freshwater snails, stoneflies, mayflies, caddisflies, and stygobites (cave-dwelling crustacean invertebrates). The Southeastern United States accounts for much of the globally significant diversity. For example, many of the approximately 340 species of the freshwater crustaceans (crayfish, shrimps, scuds, etc.) known from North America north of Mexico occur here (Hobbs 1981, Schuster 1997), and new species are still being discovered and described from the region (see Thoma 2000, for example). Crustaceans occur in all habitat types. They are cave dwellers and surface-water dwellers, and some build burrows in damp areas. Crustaceans are important members of the food web as they process leaves and other organic matter, and they provide food for fish and other animals, including humans (Pfieger 1996).

Insects also contribute tremendously to the diversity of aquatic animals in the Southeast. Morse and others (1997) discussed four important groups of insects (mayflies, stoneflies, caddisflies, and dragonflies and damselflies). They made many of the same observations about the importance of the Southeast for these insects. Of the more than 11,000 species known from North America north of Mexico, nearly half are in the Southeast (Morse and others 1997). Like crayfish, mussels, and snails, the aquatic stages of these insects are found in all types of aquatic habitats. Although some are predators (dragonflies), these aquatic insects are also important components of aquatic communities because they shred leaves and other organic matter and serve as important food sources for many fish. They are also useful indicators of water quality (Harris and others 1991).

Of the World's freshwater mussels, 91 percent occur in this region. In addition, more than half of the known fingernail clams and snails are found in the Southeastern United States (Neves and others 1997). Mollusks are found in a wide variety of habitats, but more occur in riverine systems than other habitat types (Neves and others 1997). Mussels have been described as important indicators of water quality because they are filter feeders and highly susceptible to poor water quality. They are also major food sources for many fish, reptiles, and some terrestrial animals. Mussels have also been important commercially, as the raw materials for the pearl button industry of the early 20th century and "blanks" for the Asian cultured pearl industry (Jenkinson and Todd 1997).

Of the approximately 850 species of freshwater mollusks in North America, 516 are snails, and more than half of these are found in the Southeastern United States (Neves and others 1997).

Little is known of the taxonomy of this group of mollusks, with many species still being described. Little is known of the ecology and life history of most snails, and they are difficult to identify. Distributions (especially historical versus current) are poorly known. Therefore, it is difficult to accurately assign conservation status (Neves and others 1997). The list included here is probably only a representative sample of snails at risk in the Southern United States.

Of the over 800 freshwater fish known from North America north of Mexico, the Southeastern United States is home to about half, many of which are found nowhere else in the World (Sheldon 1988; Warren and others 1997, 2000). In comparison with the invertebrates briefly mentioned above, much more documentation exists about North American freshwater fish. Even so, new species are still being discovered and described in the scientific literature (see Skelton 2001). Obviously, fish are important to humans for food. Their existence in the aquatic assemblage is important to freshwater mussels, as specific fish hosts are needed for the mussel to complete its larval stage and disperse (Neves and others 1997, and references therein). In addition, madtom catfish, many of which are found only in the Southeastern United States, could also be indicators of water quality. They rely on "tasting" the water to know what's around them. Their intolerance of even minute amounts of pollutants is a suggested explanation of why these small catfish are not found in areas where they were historically known (Etnier and Jenkins 1980).

In comparison with the aquatic animals mentioned above, fewer southeastern amphibian species are known (147 species). Even so, more species are found in the Southeast than anywhere else in the United States, including several salamanders that are found nowhere else in the World (Dodd 1997). Like the other animal groups mentioned, amphibians are found in a diversity of aquatic habitat types. More studies that detail their life histories may result in these secretive animals being recognized as indicators of water quality and other factors, such as the integrity of the ozone layer and the amount of ultraviolet radiation reaching Earth.

About one-fourth of the approximately 200 aquatic reptiles known from North America north of Mexico are found in the Southeastern United States (Buhlmann and Gibbons 1997). The Southeast is especially known for its diversity of aquatic turtles, many of which are commercially important as food or for the pet trade (Buhlmann and Gibbons 1997).

Unfortunately, the globally important southeastern aquatic fauna described earlier are under extreme threats because of past and present human activities in the water and on land (Benz and Collins 1997, Stein and others 2000). In fact, Ricciardi and Rasmussen (1999) projected extinction rates for North American freshwater animals at about five times that of North American terrestrial animals, and within the range of that estimated for tropical rainforests. Richter and others (1997) summarized a survey of experts on freshwater fauna in the United States, which included the same animal groups we include in this Assessment (except reptiles, which we include and they did not). They showed variation in stressors among the groups of aquatic animals considered; differences between the top listed stressors in the Eastern and Western United States; and differences between historic threats and those currently threatening these animals. In the East, sediment from agricultural nonpoint pollution was listed as the major stressor affecting the ability of aquatic animals to recover from declines. Wilcove and Bean (1994) made several recommendations for aquatic animal conservation. Master and others (1998) and Wilcove and Bean (1994) provided several case studies of cooperative projects in watersheds critically important to preserve aquatic diversity.

Methods and Data Sources

Aquatic Habitats

For this Assessment, freshwater habitats important to rare aquatic animals were classified as groundwater habitats or surface-water habitats. Ground water includes those in caves, and also springs and seeps. Surface-water habitats include standing water (lakes, ponds, oxbows, beaver ponds, swamps, bogs, and some wetland areas) and flowing water (rivers and streams). These two divisions are, obviously, generalizations of the immense diversity of aquatic habitats that exist in the South, and grade from one to another (see, for example, discussions by Vannote and others 1980, Mishall and others 1983). Aquatic systems are not only connected but are also completely intergraded between what is typically referred to as an aquifer to a lake or a river. By defining these broad categories and attempting to determine a primary habitat and in some cases a secondary habitat for each species considered in this Assessment, we were able to more thoroughly discuss the biological significance of these habitats and the factors threatening the species found there.

Because they are generally threatened by the same factors, permanently flooded ponds were not distinguished from ephemeral ponds in this discussion. Rivers were defined as flowing waters exclusive of headwater tributaries. Headwater tributaries include both perennial and intermittent streams.

Aquatic Species

Several agencies and conservation organizations track the distribution and conservation status of species in the United States. The U.S. Fish and Wildlife Service (USFWS) maintains a list of species that have officially been proposed or listed threatened or endangered under the Endangered Species Act of 1976, as amended. They also track species, called candidates, for which insufficient information exists to warrant formal listing. Before species are added to the list, their present and historic status must be thoroughly evaluated, and the public must be given the opportunity to provide input about proposed listings. For this reason, years often go by from the time the species is petitioned or proposed for listing until it is officially listed in the Federal Register as threatened or endangered. These procedural requirements may delay or even prevent some species from being listed.

Another ranking is managed by the Association for Biodiversity Information (ABI). The ABI is a nonprofit organization founded by The Nature Conservancy and the Natural Heritage Network (NatureServe

2000, Stein and others 2000). The list managed by ABI is more inclusive, and uses standardized criteria in an attempt to objectively rank individual species across their native ranges. This global ranking, or G rank, ascribes a degree of vulnerability to extinction throughout the entire range of the species. Table 23.1 gives the definitions used by ABI for the G ranks. Because this Assessment is concerned with range-wide sustainability, only species with ranks of G3 and lower (including GX and GH) were included (table 23.2) (fig. 23.1). Species ranked G4 or higher are apparently secure throughout their native ranges at present. ABI updates its list three times a year, and experts review the status of all listed species and potential new entries. The USFWS draws upon ABI information and on

Table 23.1—Definitions for various levels of imperilment given for individual species by the Association for Biodiversity Information used in this Assessment

Rank	Definition
GX	**Presumed extinct** (species)—Believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat and virtually no likelihood that it will be rediscovered. Eliminated (ecological communities)—Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic species.
GH	**Possibly extinct** (species)—Known from only historical occurrences but may nevertheless still be extant; further searching needed. Presumed eliminated (historic, ecological communities)—Presumed eliminated throughout its range, with no or virtually no likelihood that it will be rediscovered, but with the potential for restoration, for example, American chestnut (forest).
G1	**Critically imperiled**—Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2	**Imperiled**—Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
G3	**Vulnerable**—Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations) or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4	**Apparently secure**—Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery) and usually widespread. Apparently not vulnerable in most of its range but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
G5	**Secure**—Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.
T#	**Infraspecific taxon** (trinomial)—The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. A T subrank cannot imply the subspecies or variety is more abundant than the species, for example, a G1T2 subrank should not occur. A vertebrate animal population (e.g., listed under the U.S. Endangered Species Act or assigned candidate status) may be tracked as an infraspecific taxon and given a T rank; in such cases a Q is used after the T-rank to denote the taxon's informal taxonomic status.
?	**Inexact numeric rank**—Denotes inexact numeric rank
Q	**Questionable taxonomy that may reduce conservation priority**— Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank.

Source: The Association for Biodiversity Information (ABI) maintains an electronic database (NatureServe 2000).

Table 23.2—Aquatic species in seven taxonomic groups selected for evaluation of their vulnerability to extinction based on global ranking received from the Association of Biodiversity Information[a]

Taxonomic group	Date of database query	Global rank G1-G5	Species eliminated[b]	Rare aquatic species[c]	Group with inadequate data
					Percent
Crustaceans	5/16/00	335	176	159	5
Insects	8/17/01	1170	994	176	37
Snails	5/16/00	277	154	123	9
Mussels	7/15/01	312	121	191	2
Fish	5/17/00	810	645	165	8
Amphibians	5/17/00	218	187	31	0
Reptiles	5/17/00	369	350	19	1
Total		3,491	2,627	864	

[a] Global rankings are based on queries of the database (NatureServe 2000) on the dates indicated.
[b] Species were eliminated from further consideration because their global ranking exceeded G3, they were terrestrial or marine, their taxonomy was undetermined, or their distribution was unknown.
[c] The remaining species evaluated included those with global ranks of G1-G3, T1-T3, GH, and GX.

many of the same experts for updates to its list. The ABI source was used for this Assessment to produce the list of potentially imperiled aquatic species because it is generally more current and comprehensive than the USFWS list. This list was supplemented by six fish and three crayfish from American Fisheries Society (AFS) expert committees on the status of crayfish, mussels, and fish (Taylor and others 1996; Williams and others 1989, 1993).

Additionally, only species that spend a portion of their life cycle in a freshwater environment, including crustaceans, insects, snails, mussels, fish amphibians, and reptiles were included in this chapter. Finally, we needed adequate information to evaluate species distributions and life histories. Species with a "?" or "Q" following their G rank were not included in the lists produced for this Assessment. Table 23.2 displays the percentage of each taxonomic group that had inadequate information. While these latter species were omitted from this Assessment, their importance should not be overlooked. Many of these animals, in fact, may be extremely imperiled. The lack of distributional, taxonomic, and ecological information on these species represents a major data gap for aquatic species in the South.

The ABI database was searched for seven groups of aquatic animals: crustaceans, insects, snails, mussels, fish, amphibians, and reptiles. Search dates were May 15, 16, and 17, 2000 for all seven groups. A major update to the database was incorporated by ABI several months later. Second searches were conducted on July 15, 2001, for mussels and August 17, 2001, for insects. The results of these searches were used in this Assessment. Table 23.2 lists the taxonomic groupings, and figure 23.1 displays relative proportion of the 864 rare aquatic species selected by the criteria listed above. The lists of crayfish, mussels, and fish were compared to lists of vulnerable species published by the AFS (Taylor and others 1996, Warren and others 2000, Williams and others 1993). The AFS lists excluded the Rio Grande watershed. The only other differences between the AFS and ABI lists were six fish and three crayfish, which were added to the ABI list and considered in this Assessment. The mussel lists were in complete agreement.

With the exception of insects, the number of species ranked G1 to G5 displayed in table 23.2 represents a close approximation of the number of described species in each of the taxonomic groups in the South.

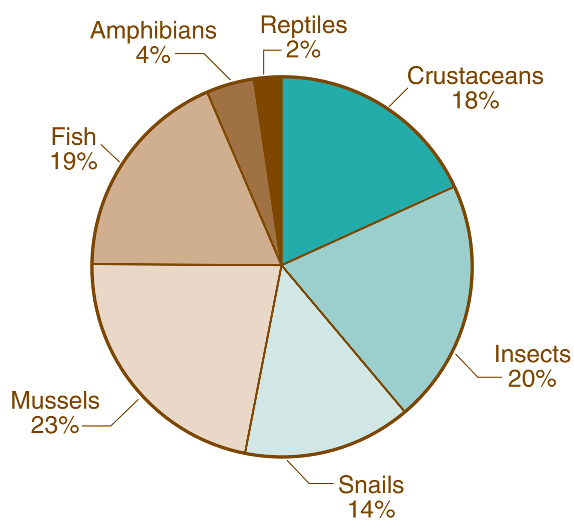

Figure 23.1—The 864 rare aquatic species evaluated are distributed among 7 major taxonomic groups.

Discussion

The “Aquatic Habitats” section, which follows, discusses the potential physical and chemical impacts of human activities on the broad categories of aquatic habitats discussed here. The distributions and biological effects of human activities on the distributions of aquatic animals included in this Assessment are summarized in the “Aquatic Species” section.

Aquatic Habitats

The number of species in each taxonomic group dependent on the five aquatic habitats is shown in table 23.3. If appropriate, primary and secondary habitats were evaluated for aquatic animals that are not restricted to one habitat type. For example, some species migrate between different habitats for different parts of their life cycles. In the study area, lakes and ponds contained fewer rare aquatic species than rivers and streams, subterranean waters, or springs.

Ground-water habitats—Subterranean aquatic systems are widely dispersed across the South. Caves and springs are widely distributed in the Southeastern United States (Hobbs 1992). Although the distribution of many cave-dwelling animals is not well known (Hobbs 1992, Peck 1998), we do know that aquifers and springs in Texas support rare crayfish, beetles, salamanders, and fish. North Carolina and Virginia caves are home to rare shrimp, aquatic sow bugs, scuds, and crayfish. The springs of Florida and South Carolina provide habitats for unique snails and fish. Tennessee, Alabama, Kentucky, and Arkansas are known for their cave salamanders, as well as cavefish, crayfish, and shrimp (Hobbs 1989, NatureServe 2000).

Larger springs may have a unique assemblage of spring-adapted animals. The spring runs flowing from them then may have their own unique assemblages (Hubbs 1995) and share some species with the spring habitats.

Many of the species restricted to subterranean aquatic systems are narrow endemics, occurring only in a few isolated localities (Burr and Warren 1986, Hobbs 1989, Hubbs 1995, NatureServe 2000). Several characteristics that allow animals restricted to these habitats to be extremely efficient at using the available, often limited, resources could result in declines. These include small body size, late maturity, and infrequent reproduction, which result in low reproductive rates and small population size (Hobbs 1992).

Physical and chemical threats to ground-water habitats—Chemical and physical conditions of waters in caves and springs are relatively stable (Hobbs 1992, Hubbs 1995). The rare animals adapted to subterranean areas are threatened by activities that alter these stable conditions. Subterranean systems are being affected by rapid agricultural and urban growth, which can dewater aquifers and change water chemistry (Hobbs 1992). Ground water can be contaminated by domestic, municipal, agricultural, and industrial wastes. Changes in the vegetative cover of the drainage basin can alter runoff patterns. Flooding from artificial lakes, pesticides, and sedimentation associated with deforestation and urbanization in the watersheds can also affect ground-water habitats (Hobbs 1992, Petranka 1998).

Recharge areas for springs and caves can be of considerable size (Hubbs 1995). Thus, water quality and quantity can be affected by activities throughout the recharge area, often long distances away from a cave or spring. However, the recharge areas for many important spring or cave systems are not known. Even if the recharge area is known, the potential effects of human activities in these areas are not well documented. Hobbs (1992) suggested that overextraction of ground water may slowly concentrate metals or other pollutants to the point that they ultimately become lethal to specialized aquatic cave-dwelling animals.

Because of the value of a reliable clean, clear water supply, springs are often modified so they can be used as water sources. Aquatic vegetation, which can be very important to spring-adapted animals, is often removed. Etnier and Starnes (1991) noted that Tennessee’s spring-adapted fish are

Table 23.3—Habitat preferences for rare aquatic species[a]

Taxonomic group	Ground water		Lakes		Ponds		Rivers		Streams	
	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
Crustaceans	40	40	0	0	52	4	0	0	67	115
Insects	24	28	2	1	2	5	40	43	108	99
Snails	27	18	0	0	2	2	81	77	13	26
Mussels	0	0	0	0	0	0	185	185	6	6
Fish	18	14	1	1	1	2	76	79	69	69
Amphibians	17	17	0	0	6	6	0	0	8	8
Reptiles	0	0	0	0	5	7	7	9	10	0
Total	126	117	3	2	68	26	389	393	281	323

Primary and secondary habitat types (column group heading).

Prim. = primary; Sec. = secondary. These designations do not necessarily imply a consistent order or ranking of importance to the taxonomic group.
[a] Five general habitat categories are evaluated in the Assessment; only habitats that are significantly used are considered.

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jeopardized more frequently than would be expected in comparison with fish adapted to other aquatic habitat types. They concluded that the habitats themselves are jeopardized. The same factors that can affect water chemistry in the recharge areas for cave habitats can affect springs. In particular, withdrawal of ground water can affect the quality and quantity of spring water by concentrating dissolved chemicals and reducing flow (Hobbs 1992). Hubbs (1995) described this condition as an artificial drought. Hobbs (1992) commented on the need for more States to adopt cave protection laws, and suggested that purchasing important areas for preserves, restricting entry into caves, and public education are necessary means of conserving cave and spring-adapted animals.

Lakes—Natural lakes are rare in the South. Some of the most important natural lakes include the Carolina bay lakes, cypress ponds, and lakes formed in the floodplains of large rivers (Crisman 1992). Florida and the Coastal Plain of North Carolina have the most natural lakes. Comparatively fewer rare aquatic animals are dependent on lake habitats than other aquatic habitat types in the South. Construction of dams on the larger rivers in the South has created many reservoirs, which have characteristics similar to natural lakes. However, these artificial habitats do not benefit these rare species.

Physical and chemical threats to lake habitats—Lake habitats are threatened by increased sedimentation and eutrophication. These nonpoint-pollution sources are discussed in detail in chapter 19. The most significant threat to natural lake habitats is urban development along the shores, which increases eutrophication (NatureServe 2000). Guidelines for septic tank drainage need to be implemented and enforced to protect this habitat type.

Ponds—Permanent and ephemeral ponds are widely dispersed and numerous in the South. Many low-gradient streams have associated oxbows, beaver ponds, and swamps. Rare species from every taxonomic group except mussels depend on ponds. Crustaceans are among the most rare species associated with these habitats. Many amphibian species use only ephemeral ponds for spawning, thus avoiding predation on their eggs and tadpoles by species that require permanent ponds. Some fish (slackwater and trispot darters, for example) use seasonally flooded wetland areas for spawning (McGregor and Shephard 1995, Ryon 1986).

Physical and chemical threats to pond habitats—The quality and quantity of these habitats have been reduced by channel straightening, beaver trapping, and drainage systems. Urban development and intensive agricultural and silvicultural activities that drain or fill wetlands are detrimental to permanent and ephemeral ponds (Palis 1996, Petranka 1998, Vickers and others 1985).

The removal of beaver during the past 400 years has reduced the number of wetlands in the South (White and Wilds 1997). Beaver have recovered in many areas, but populations in the Southern Appalachian Mountains have been slow in returning. Absence of this keystone species contributes to the isolation of many amphibian populations (Herrig and Bass 1998).

In some areas, fire suppression has allowed shading to develop, resulting in colder temperatures in the ponds and extension of the maturation time for tadpoles (NatureServe 2000).

Pesticides and accidental chemical spills may threaten species dependent on pond habitats because of the small volume and isolated nature of these waters.

Rivers—Rare mussels, snails, and fish have the greatest dependency on riverine habitats (table 23.3). While the numbers of rare insects and reptiles that rely on this habitat type are small, riverine habitats support about half the rare species in each of these groups. None of the rare crustaceans or amphibians included in this Assessment is known to depend exclusively on river habitats.

Physical and chemical threats to river habitats—At least one-sixth of all river miles in the United States are now impounded (Abell and others 2000, Benke 1990). Dams have created barriers to dispersal that have genetically isolated populations of many aquatic animals, inhibited movement, or created unsuitable habitats for the fish that are hosts to the mussels' larvae. Dams have blocked migration routes for herrings, suckers, and sturgeons.

Flow releases from dams rarely emulate natural, daily, or seasonal discharges; the results are marginal-to-unsuitable habitats for the native aquatic species living in these tailwaters. In extreme cases, unsuitable conditions may extend for up to 125 miles downstream (Abell and others 2000).

Dams can convert shallow, flowing, oxygenated streams into deep, still, stagnant pools. In North America, at least 36 species of snails from the Mobile River system have become extinct since the beginning of European settlement (U.S. Department of the Interior, Fish and Wildlife Service 2000). A series of dams on the Coosa River is believed to have caused the immediate extinction of 20 snail species (Lydeard and Mayden 1995, U.S. Department of the Interior, Fish and Wildlife Service 2000). Reservoirs have flooded much of the flowing water habitats needed for stream-dwelling or spring animals (NatureServe 2000). For example, the Amistad gambusia went extinct when Amistad Reservoir flooded its only known location (NatureServe 2000). Dams collect sediment, degrading the habitat for mussels and their fish hosts (Parmalee and Bogan 1998).

Channelization and commercial sand and gravel dredging operations decrease river habitat diversity, directly remove mussels from their beds, and create "motionless pools alternating with unbroken stretches where silt and sand constantly scud along the bottom" (Hart and Fuller 1974).

Petroleum spills; urban and agricultural pesticides; and chemical, manufacturing, and wood product wastes are among the most insidious pollutants (Abell and others 2000, Hart and Fuller 1974). The impacts from these pollutants are often both immediate and persistent.

Sediment contributes to river degradation (NatureServe 2000). Sediment sources are discussed in detail in chapter 19. The turbidity associated with sediment runoff can interfere with feeding for both sight and filter feeders and can shade out aquatic vegetation or erode away attached algae. Once the sediment settles into the river, it may bury slow-moving benthic organisms and eggs, clog interstitial spaces, and armor the stream bottom.

Conant and Collins (1998) reported that egg-laying reptiles whose nests are on sandbars or banks of rivers could be affected by various human activities. The habitats required for nesting could be covered by impoundments or affected by channel maintenance dredging (Dodd 1997). Eggs, which often remain buried for several months, may also be destroyed by off-road vehicles; agricultural, silvicultural, and mining activities; road construction; and residential or industrial construction.

Streams—Both perennial and intermittent streams are important to aquatic species. Individuals from all of the rare aquatic groups considered in this Assessment depend on stream habitats. Stream habitats and the composition and diversity of aquatic animals change in a predictable way as stream order (size) increases (Sheldon 1988). More rare crustacean species are associated with intermittent streams than any other aquatic species group. Further studies of aquatic insects, however, may reveal an even stronger dependency by this group on intermittent streams. Wallace and others (1992) suggest that headwater streams of the Southern Appalachians probably contain a greater diversity of aquatic insects than any other region of North America, and that fish and salamander diversity is also relatively high there.

Physical and chemical threats to stream habitats—Removal of riparian vegetation along streams (Petranka 1998) and intensive ground disturbance within riparian areas may adversely alter stream habitats, especially for crustaceans and amphibians (Petranka 1998, Petranka and others 1994).

Because they have less volume of water, small streams may be exposed to higher concentrations of pollutants, including sediments, than rivers. Petroleum spills, urban and agricultural pesticides, and industrial wastes are particularly damaging to streams (Abell and others 2000, Hart and Fuller 1974) and can affect individuals from all taxonomic groups. Water withdrawals for rural and urban uses may excessively reduce base flow of small streams, further shrinking available habitat (Abell and others 2000).

Indirect impacts of pollutants or habitat alterations may occur through a reduction in food organisms for the animals discussed (NatureServe 2000). Other examples of more direct effects of human activities include disturbances to the nests of egg-laying reptiles (Conant and Collins 1998). Etnier and Starnes (1991) reported a disproportionately high number of Tennessee's rare fish are in medium-sized rivers. They hypothesize that impoundments on medium rivers produce habitat changes that are not as well tolerated by animals adapted to streams of this size, relative to those adapted to larger river habitats. They concluded that the habitats themselves are threatened.

Aquatic Species

Southeastern aquatic animal diversity is globally significant. A recurring theme in the chapters edited by Benz and Collins (1997) is that, although the importance of the aquatic diversity of the Southeastern United States is well known to biologists, there is still much that we do not know. Although the worldwide biodiversity crisis is well publicized, very little is known about aquatic systems, especially the exceptional diversity indigenous to North America. The lists of rare aquatic animals included in this Assessment should be considered as indicators of the groups as a whole, and not as inclusive lists. Lydeard and Mayden (1995) suggested that protecting habitats important to a majority of southeastern aquatic animals would result in conservation of a high proportion (more than 80 percent) of North American aquatic biodiversity. Next, we focus on what is known of geographical distribution patterns and biological characteristics that make these rare species vulnerable.

Important life-history characteristics, including feeding, reproduction, and escape mechanisms, are reviewed for each taxonomic group. These characteristics govern the sensitivity of organisms to ecological stressors, especially sediment, during the most critical stages in their life histories. Fish are too diverse in their life histories to include in a single group and have been split into families for analysis.

Crustaceans—The 159 rare crustaceans included in this Assessment (table 23.4) belong to three orders: (1) decapods (containing shrimp and crayfishes), (2) isopods (sowbugs), and (3) amphipods (sideswimmers, or scuds) (NatureServe 2000, Pennak 1989) (fig. 23.2). Although Shuster (1997) commented that there is not enough known about many crustacean groups to make a determination about conservation status, we include species in this Assessment for which there are enough available data to indicate their rarity. All of these rare crustaceans are scavengers feeding on dead or dying animals and plants. The females of these three orders protect their eggs and young by retaining them in a marsupial pouch until they reach their first instar.

Habitats used by crustaceans include four broad aquatic habitat types: (1) caves and subterranean streams, (2) ponds, (3) burrows

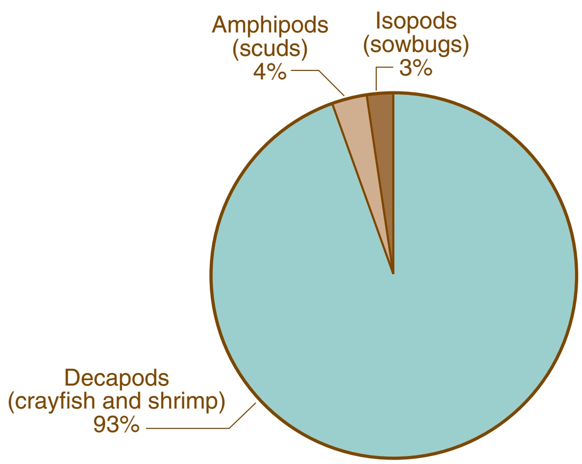

Figure 23.2—The 159 rare aquatic crustacean species evaluated belong to 3 orders.

Table 23.4—The rare aquatic crustaceans evaluated included 159 species, of which 9 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank	Primary habitat[b]	Secondary habitat[b]
Antrolana lira	Madison cave isopod	LT	G1		Ground water
Bouchardina robisoni	A crayfish		G1	Streams	Streams
Caecidotea sp. 7	A cave isopod (Lee County)		G1	Ground water	Ground water
Cambarellus blacki	Cypress crayfish		G1	Ponds	Ponds
Cambarellus diminutus	Least crayfish		G3	Streams	Streams
Cambarellus lesliei	A crayfish		G3	Streams	Streams
Cambarellus ninae	A crayfish		G3	Streams	Streams
Cambarellus schmitti	A crayfish		G3	Streams	Streams
Cambarus aculabrum	A crayfish	LE	G1	Ground water	Ground water
Cambarus angularis	A crayfish		G3	Streams	Streams
Cambarus batchi	Bluegrass crayfish		G3	Ponds	Streams
Cambarus bouchardi	Big South Fork crayfish		G2G3	Streams	Streams
Cambarus catagius	Greensboro burrowing crayfish		G3	Ponds	Streams
Cambarus causeyi	A crayfish		G1	Streams	Streams
Cambarus chaugaensis	A crayfish		G2	Streams	Streams
Cambarus conasaugaensis	A crayfish		G3	Streams	Streams
Cambarus coosawattae	A crayfish		G1	Streams	Streams
Cambarus cracens	A crayfish		G1	Streams	Streams
Cambarus cryptodytes	Dougherty plain cave crayfish		G2	Ground water	Ground water
Cambarus cymatilis	A crayfish		G1	Ponds	Streams
Cambarus englishi	A crayfish		G3	Streams	Streams
Cambarus extraneus	Chickamauga crayfish		G2	Streams	Streams
Cambarus fasciatus	A crayfish		G2	Streams	Streams
Cambarus georgiae	Little Tennessee crayfish		G1	Streams	Streams
Cambarus harti	Piedmont blue burrower		G1	Ponds	Streams
Cambarus howardi	Chattahoochee crayfish		G3	Streams	Streams
Cambarus jonesi	Alabama cave crayfish		G3	Ground water	Ground water
Cambarus miltus	Rusty grave digger		G2	Ponds	Streams
Cambarus obeyensis	Obey crayfish		G2	Streams	Streams
Cambarus ornatus	A crayfish		G3	Streams	Streams
Cambarus parrishi	A crayfish		G1	Streams	Streams
Cambarus pristinus	A crayfish		G1	Streams	Streams
Cambarus pyronotus	Fire-back crayfish		G2	Ponds	Streams
Cambarus scotti	A crayfish		G3	Streams	Streams
Cambarus sp. 3	(Shelta Cave, Madison Co., AL) (Aviticambarus, Sp B)		G1	Ground water	Ground water
Cambarus speciosus	A crayfish		G2	Streams	Streams
Cambarus spicatus	A crayfish		G3	Streams	Streams
Cambarus strigosus	A crayfish		G2	Ponds	Streams
Cambarus subterraneus	A crayfish		G1	Ground water	Ground water
Cambarus tartarus	Oklahoma cave crayfish		G1	Ground water	Ground water
Cambarus truncatus	Oconee burrowing crayfish		G1	Ponds	Streams
Cambarus unestami	A crayfish		G2	Streams	Streams
Cambarus zophonastes	Hell Creek cave crayfish	LE	G1	Ground water	Ground water
Distocambarus carlsoni	Mimic crayfish		G3	Ponds	Streams
Distocambarus crockeri	A crayfish		G3	Ponds	Streams
Distocambarus devexus	A crayfish		G1	Ponds	Streams
Distocambarus youngineri	A crayfish		G1	Ponds	Streams
Fallicambarus burrisi	A crayfish		G3	Ponds	Streams
Fallicambarus danielae	Speckled burrowing crayfish		G2	Ponds	Streams
Fallicambarus devastator	Texas prairie crayfish		G3	Ponds	Streams
Fallicambarus gilpini	A crayfish		G1	Ponds	Streams
Fallicambarus gordoni	A crayfish		G1	Ponds	Streams
Fallicambarus harpi	A crayfish		G1	Ponds	Streams

continued

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Table 23.4—The rare aquatic crustaceans evaluated included 159 species, of which 9 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank	Primary habitat[b]	Secondary habitat[b]
Fallicambarus hortoni	Hatchie burrowing crayfish		G1	Ponds	Streams
Fallicambarus jeanae	A crayfish		G2	Ponds	Streams
Fallicambarus macneesei	A crayfish		G3	Ponds	Streams
Fallicambarus petilicarpus	A crayfish		G1	Ponds	Streams
Fallicambarus strawni	A crayfish		G1G2	Ponds	Streams
Faxonella blairi	A crayfish		G2	Ponds	Ponds
Faxonella creaseri	A crayfish		G2	Ponds	Ponds
Hobbseus attenuatus	Pearl riverlet crayfish		G2	Streams	Streams
Hobbseus cristatus	A crayfish		G3	Ponds	Streams
Hobbseus orconectoides	Oktibbeha riverlet crayfish		G3	Ponds	Streams
Hobbseus petilus	Tombigbee riverlet crayfish		G2	Streams	Streams
Hobbseus valleculus	Choctaw riverlet crayfish		G1	Streams	Streams
Hobbseus yalobushensis	A crayfish		G3	Streams	Streams
Lirceus usdagalun	Lee County cave isopod	LE	G1	Ground water	Ground water
Orconectes bisectus	Crittenden crayfish		G2	Streams	Streams
Orconectes blacki	A crayfish		G2	Streams	Streams
Orconectes carolinensis	North Carolina spiny crayfish		G3	Streams	Streams
Orconectes cooperi	A crayfish		G1	Streams	Streams
Orconectes eupunctus	Coldwater crayfish		G3	Streams	Streams
Orconectes hartfieldi	A crayfish		G2	Streams	Streams
Orconectes hathawayi	A crayfish		G3	Streams	Streams
Orconectes holti	A crayfish		G3	Streams	Streams
Orconectes incomptus	Tennessee cave crayfish		G1	Ground water	Ground water
Orconectes jeffersoni	Louisville crayfish		G1	Streams	Streams
Orconectes jonesi	A crayfish		G3	Streams	Streams
Orconectes kentuckiensis	A crayfish		G2	Streams	Streams
Orconectes maletae	A crayfish		G2	Streams	Streams
Orconectes marchandi	Mammoth spring crayfish		G2	Streams	Streams
Orconectes menae	A crayfish		G3	Streams	Streams
Orconectes mississippiensis	A crayfish		G2G3	Streams	Streams
Orconectes nana	A crayfish		G3	Streams	Streams
Orconectes neglectus chaenodactylus	Ringed crayfish		G5T2	Streams	Streams
Orconectes pellucidus	Eyeless crayfish		G3	Ground water	Ground water
Orconectes rafinesquei	A crayfish		G2	Streams	Streams
Orconectes ronaldi	A crayfish		G3	Streams	Streams
Orconectes saxatilis	Kiamichi crayfish		G1	Streams	Streams
Orconectes sheltae	Shelta cave crayfish		G1	Ground water	Ground water
Orconectes shoupi	Nashville crayfish	LE	G1	Streams	Streams
Orconectes virginiensis	Chowanoke crayfish		G3	Streams	Streams
Orconectes williamsi	A crayfish		G2	Streams	Streams
Orconectes wrighti	A crayfish		G1	Streams	Streams
Palaemonetes cummingi	Squirrel chimney cave shrimp	LT	G1	Ground water	Ground water
Palaemonias alabamae	Alabama cave shrimp	LE	G1G3	Ground water	Ground water
Palaemonias ganteri	Mammoth cave shrimp	LE	G1	Ground water	Ground water
Procambarus acherontis	Orlando cave crayfish		G1	Ground water	Ground water
Procambarus apalachicolae	A crayfish		G2	Ponds	Streams
Procambarus attiguus	Silver Glen Springs crayfish		G1	Ground water	Ground water
Procambarus barbiger	Jackson Prairie crayfish		G2	Ponds	Streams
Procambarus brazoriensis	Brazoria crayfish		G1	Ponds	Streams
Procambarus cometes	Mississippi flatwoods crayfish		G1	Ponds	Streams
Procambarus connus	Carrollton crayfish		GH	Ponds	Streams
Procambarus delicatus	Bigcheek cave crayfish		G1	Ground water	Ground water
Procambarus echinatus	Edisto crayfish		G3	Streams	Streams

continued

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Table 23.4—The rare aquatic crustaceans evaluated included 159 species, of which 9 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank	Primary habitat[b]	Secondary habitat[b]
Procambarus econfinae	Panama City crayfish		G1G2	Ponds	Streams
Procambarus epicyrtus	A crayfish		G3	Streams	Streams
Procambarus erythrops	Santa Fe cave crayfish		G1	Ground water	Ground water
Procambarus escambiensis	A crayfish		G2	Ponds	Streams
Procambarus ferrugineus	A crayfish		G1	Ponds	Streams
Procambarus fitzpatricki	Spinytail crayfish		G2	Ponds	Streams
Procambarus franzi	Orange Lake cave crayfish		G1	Ground water	Ground water
Procambarus gibbus	A crayfish		G3	Streams	Streams
Procambarus hagenianus vesticeps	A crayfish		G4G5T3	Ponds	Streams
Procambarus horsti	Big Blue Springs cave crayfish		G1	Ground water	Ground water
Procambarus kensleyi	A crayfish		G3	Ponds	Streams
Procambarus lagniappe	Lagniappe crayfish		G2	Streams	Streams
Procambarus latipleurum	A crayfish		G2	Ponds	Streams
Procambarus leitheuseri	Coastal lowland cave crayfish		G2	Ground water	Ground water
Procambarus lucifugus	Florida cave crayfish		G2G3	Ground water	Ground water
Procambarus lucifugus alachua	A crayfish		G2G3T2	Ground water	Ground water
Procambarus lucifugus lucifugus	A crayfish		G2G3T1	Ground water	Ground water
Procambarus lylei	Shutispear crayfish		G2	Streams	Streams
Procambarus marthae	A crayfish		G3	Streams	Streams
Procambarus medialis	Tar River crayfish		G2	Streams	Streams
Procambarus milleri	Miami cave crayfish		G1	Ground water	Ground water
Procambarus morrisi	A crayfish		G1	Ground water	Ground water
Procambarus nechesae	A crayfish		G1G2	Ponds	Streams
Procambarus nigrocinctus	A crayfish		G1G2	Streams	Streams
Procambarus nueces	A crayfish		G1	Streams	Streams
Procambarus orcinus	Woodville karst cave crayfish		G1	Ground water	Ground water
Procambarus pallidus	Pallid cave crayfish		G2G3	Ground water	Ground water
Procambarus pecki	Phantom cave crayfish		G2	Ground water	Ground water
Procambarus penni	Pearl blackwater crayfish		G3	Streams	Streams
Procambarus petersi	A crayfish		G3	Streams	Streams
Procambarus pictus	Spotted royal crayfish		G2	Streams	Streams
Procambarus pogum	Bearded red crayfish		G1	Ponds	Streams
Procambarus pubischelae deficiens	A crayfish		G5T3Q	Streams	Streams
Procambarus rathbunae	A crayfish		G2	Ponds	Streams
Procambarus regalis	A crayfish		G2G3	Ponds	Streams
Procambarus reimeri	A crayfish		G1	Ponds	Streams
Procambarus rogersi campestris	A crayfish		G4T2T3	Ponds	Streams
Procambarus rogersi expletus	A crayfish		G4T1	Ponds	Streams
Procambarus rogersi ochlocknensis	A crayfish		G4T2T3	Ponds	Streams
Procambarus rogersi rogersi	A crayfish		G4T1	Ponds	Streams
Procambarus tenuis	A crayfish		G3	Ponds	Streams
Procambarus texanus	A crayfish		G1	Ponds	Ponds
Procambarus truculentus	A crayfish		G3	Ponds	Streams
Procambarus youngi	Florida longbeak crayfish		G2	Streams	Streams
Remasellus parvus	An isopod (from FL)		G1	Ground water	Ground water
Stygobromus pecki	Peck's cave amphipod	LE	G1	Ground water	Ground water

continued

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Table 23.4—The rare aquatic crustaceans evaluated included 159 species, of which 9 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank	Primary habitat[b]	Secondary habitat[b]
Stygobromus sp. 10	A cave amphipod (Botetourt County)		G1	Ground water	Ground water
Stygobromus sp. 11	A ground water amphipod (Nelson County)		G1	Ground water	Ground water
Stygobromus sp. 12	A ground water amphipod (Rockbridge County)		G1	Ground water	Ground water
Stygobromus sp. 13	A ground water amphipod (Patrick County)		G1	Ground water	Ground water
Stygobromus sp. 9	A cave amphipod (Shenandoah County)		G1	Ground water	Ground water
Troglocambarus maclanei	Spider cave crayfish		G2	Ground water	Ground water
Troglocambarus sp. 1	A crayfish		G1	Ground water	Ground water

ABI = Association for Biodiversity Information.
[a] Federal status: LE = listed as endangered; LT = listed as threatened; PE = proposed for listing as endangered; PT = proposed for listing as threatened; C = candidate for listing.
[b] Primary and secondary habitat do not necessarily imply a consistent order or ranking of importance to the taxonomic group.
Source: NatureServe 2000a.

in stream or pond banks or in wet meadows, and (4) streams. Figure 23.3 displays the proportion of species associated with each habitat type.

Some crayfish excavate burrows, which provide protection from dehydration during dry periods (Hobbs 1976, 1989; Pflieger 1996). Burrowing crayfish are often found along stream or pond edges, but they may occur at great distances from open water in moist pastures or lawns (Pennak 1989, Pflieger 1996). The pond and stream-dwelling crayfish include burrowers and nonburrowers (Hobbs 1989), but even stream-dwelling crayfish that normally don't burrow can excavate burrows if their stream dries out. The stream-dwelling crayfish spend daylight hours hidden under rocks or organic debris in the stream channel, emerging at night to forage (Hobbs 1989). The isopods, the amphipods considered here, and 24 of the crayfish are restricted to caves and springs.

Available data indicate that these rare species are not geographically clustered but are evenly distributed around the South (fig. 23.4), except in western Texas and Oklahoma, which are devoid of rare crustaceans. Crustaceans in general, as well as the southeastern species included in this Assessment, are among the most narrowly endemic organisms known (Taylor and others 1996). For example, of the 159 species discussed in this Assessment, 144 are known from relatively small geographical areas (fig. 23.5).

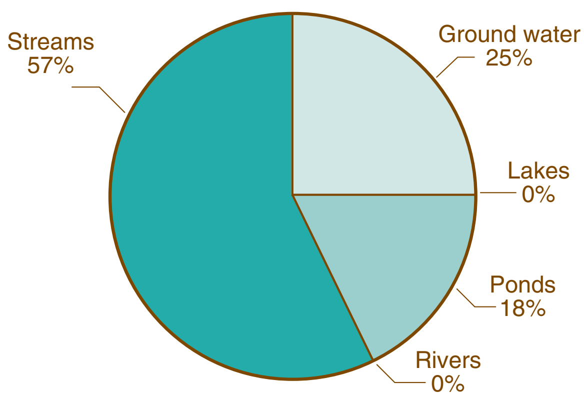


Figure 23.3—The 159 rare aquatic crustaceans are found in ground water, streams, and ponds. They are absent from large bodies of water (rivers and lakes).

Threats to crustaceans—The extremely restricted ranges of many crustaceans amplify the effects of even relatively small-scale impacts. Taylor and others (1996) noted, "Taxa restricted in range to an area of 100 square miles or less are particularly vulnerable to habitat destruction or degradation . . . ." Any degradation severe enough to cause extirpation could also cause total extinction.

For example, three of the four pond-dwelling crayfish listed in table 23.4 are known from a single locality, while the range of the fourth is restricted to only a slightly larger area. However, these crayfish may tolerate periodic desiccation of the ponds they live in because they can burrow if the ponds dry (Hobbs 1989).

In addition to pollution and habitat alteration, threats to stream-dwelling crayfish include overcollecting for bait or food, competition from exotic crayfish, and predation from introduced (stocked) fish (NatureServe 2000, Taylor and others 1996). Another nonnative pest species, the zebra mussel, can attach so densely to crayfish that the crayfish are unable to shed their carapaces and grow (Schuster 1997).

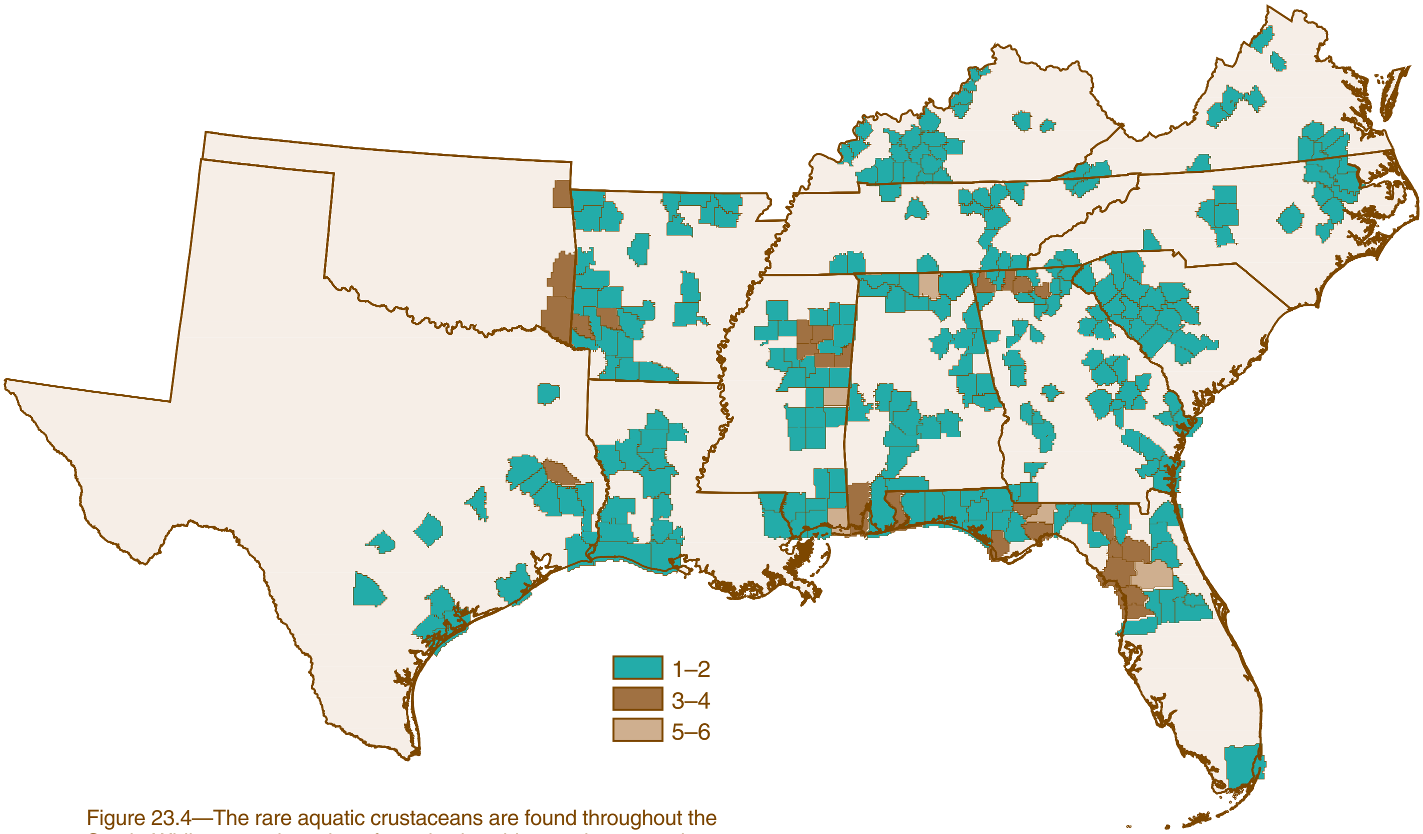


Figure 23.4—The rare aquatic crustaceans are found throughout the South. While some clustering of species is evident and rare species are absent from western Texas and Oklahoma, distribution is surprisingly uniform.

Figure 23.5—Endemism is extremely high in crustaceans. Over 90 percent of the rare aquatic crustaceans have native ranges smaller than five counties and over one-third are restricted to a single county.

The rare ground-water inhabiting species of isopods, amphipods, and crayfish are being impacted by dewatering of aquifers, pollution, and sedimentation.

Future for crustaceans—Regardless of the preferred habitat, the viability of many of the rare crustaceans is most threatened because of their small ranges. Impacts to habitats that would reduce or extirpate local populations of other taxonomic groups might result in extinction of some crustaceans (Taylor and others 1996). Crayfish are somewhat tolerant of desiccation, but permanent conversion of wetlands to pasture or urban uses could eliminate populations and lead to extinctions. Best management practices directed at the protection of wetlands and riparian areas will increase the potential viability of these species.

Areas that contain nonnative crayfish associated with "bait-bucket" introductions could see the natives continue to decline (Taylor and others 1996).

Insects—The 176 rare aquatic insects (table 23.5) addressed in this Assessment include organisms from five separate orders: (1) Plecoptera

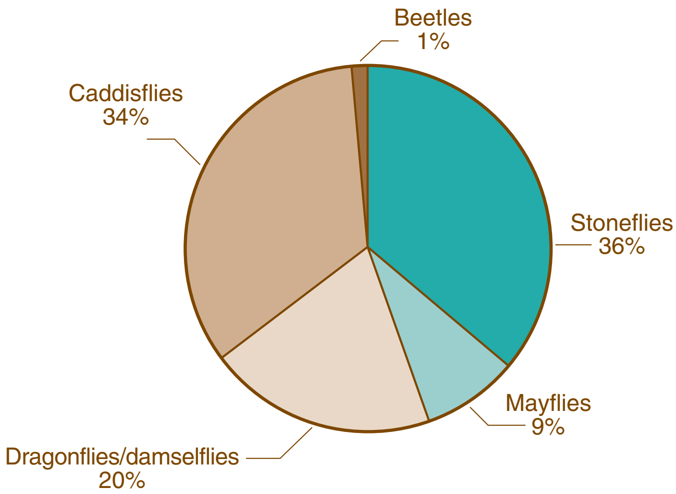


Figure 23.6—The 176 rare aquatic insect species evaluated belong to 5 orders.

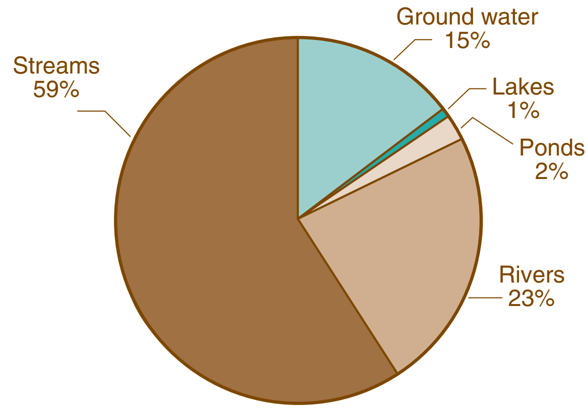


Figure 23.7—The 176 rare aquatic insects are found in all 5 habitat types. Rivers support more than one-half of these species. Still-water habitats (lakes and ponds) provide habitat for the fewest rare insect species.

(stoneflies, 64 species), (2) Ephemeraoptera (mayflies, 15 species), (3) Odonata (dragonflies, 31 species, and damselflies, 4 species), (4) Trichoptera (caddisflies, 60 species), and (5) Coleoptera (aquatic beetles, 2 species) (Meritt and Cummins 1984) (fig. 23.6). These organisms use all five habitat types but are predominately found in rivers and streams (fig. 23.7). With the exception of the two beetle species, all of the adult insects considered in this Assessment are terrestrial, returning to the aquatic environment only to deposit eggs.

The stoneflies are most often associated with flowing water where they seek hiding cover among rocks, algae, and organic debris. They are very sensitive to low oxygen levels. Eggs are released into the water column or attached to underwater structures. Once the nymphs hatch, they spend from 1 to 3 years in the water. Most nymphs are carnivorous, feeding on aquatic insects; however, some species feed on algae, bacteria, and vegetable detritus (Pennak 1989).

Mayflies are very similar to stoneflies in their habitats and preferred habitats. Most species in this group, however, are herbivorous. Some species are carnivorous, while others feed on organic detritus (Pennak 1989).

Dragonflies and damselflies are similar to each other in many of their habitat needs (Meritt and Cummins 1984). They are sight feeders, feeding on insects, worms, small crustaceans, and mollusks, and cannot feed adequately in turbid water. Depending on the species and water temperature, nymphs may spend a few months to several years in the water (Pennak 1989).

The caddisflies typically produce one or two generations per year. In most species, the adult female enters the water and swims to the bottom to attach eggs to the substrate. Many nymphs build elaborate cases to provide protection and attachment. Feeding strategies include grazers and scrapers that feed on algae and detritus attached to rocks; strainers and net filters that collect suspended organic matter from the water column; and carnivores that feed on insect, worms, and small crustaceans (Pennak 1989).

The aquatic larvae life stage of the two beetle species listed in table 23.5 are restricted to springs and subterranean flows associated with Edward's aquifer in central Texas (NatureServe 2001). These larvae crawl along the bottom feeding on algae and plant detritus. In addition, since neither species is capable of flight, the adults are also closely linked to these aquatic habitats, and dispersal is limited to water movement through the aquifer (Pennak 1989).

Morse and others (1997) noted that insects are generally small, cryptic, little-known animals. Few biologists are expert in their identification or ecological requirements. In their discussion of rare southeastern insects, Morse and others included a list of dragonflies and damselflies, mayflies, stoneflies, and caddisflies. These groups are apparently better known than some other groups of aquatic insects (Harris and others 1991, Wiggins 1977, for example).

With the exception of the narrow endemics, whose geographic ranges are relatively small, the insects are wide ranging, with their distributions often including several States. However, these large ranges frequently include vast areas of unoccupied habitats; the areas currently occupied by these insects are often highly localized. Because the adults can be far ranging and more mobile than many of the other aquatic animals discussed in this Assessment, they are likely to reoccupy areas where they have been previously extirpated (NatureServe 2001). County occurrence data are not available for most of these species; consequently, no distribution map could be produced.

Threats to insects—Because of restricted geographic ranges, or highly localized populations of wide-ranging species, the insects are subject to extinction from any factors that alter their habitats severely enough to extirpate single populations. In addition to water pollution, or other factors that affect food organisms, runoff that results in increased turbidity could interfere with sight-feeding ability and adversely affect these predatory insects.

Sediment can also affect filter-feeding caddisflies, some of which require stable stream bottoms with spaces among rocks for attachment of filter nets. Many caddisflies, stoneflies, mayflies, and other insect larvae require sediment-free surfaces for grazing and prey production.

Table 23.5—The rare aquatic insects evaluated included 176 species, of which 2 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]
Agarodes libalis	Spring-loving psiloneuran caddisfly		G1G2	Ground water	Ground water
Cheumatopsyche comis	Flint's net-spinning caddisfly		G3	Ground water	Ground water
Cheumatopsyche morsei	A common netspinning caddisfly		G1	Ground water	Ground water
Chimarra holzenthali	A caddisfly		G1	Ground water	Ground water
Glyphopsyche sequatchie	Sequatchie caddisfly	C	G1	Ground water	Ground water
Heterelmis comalensis	Comal Springs riffle beetle	LE	G1	Ground water	Ground water
Hydroptila ouachita	A purse casemaker caddisfly		G1	Ground water	Ground water
Hydroptila wakulla	Wakulla springs vari-colored microcaddis		GH	Ground water	Ground water
Isoperla szczytkoi	A stonefly		G1	Ground water	Ground water
Megaleuctra flinti	A stonefly		G2	Ground water	Ground water
Megaleuctra williamsae	Williams' rare winter stonefly		G2	Ground water	Ground water
Oconoperla innubila	A stonefly		G2	Ground water	Ground water
Ostrocerca prolongata	A stonefly		G3	Ground water	Ground water
Stygoparnus comalensis	Comal Springs dryopid beetle	LE	G1	Ground water	Ground water
Viehoperla ada	A stonefly		G3	Ground water	Ground water
Zapada chila	A stonefly		G2	Ground water	Ground water
Agarodes ziczac	Zigzag blackwater caddisfly		G1	Streams	Ground water
Argia leonorae	Leonora's damselfly		G3	Streams	Ground water
Austrotinodes texensis	Texas austrotinodes caddisfly		G2	Streams	Ground water
Ceratopsyche etnieri	Buffalo Springs caddisfly		G1G3	Streams	Ground water
Chimarra florida	Floridain finger-net caddisfly		G1G2	Streams	Ground water
Cordulegaster sayi	Say's spiketail		G2	Streams	Ground water
Gomphus consanguis	Cherokee clubtail		G2G3	Streams	Ground water
Lepidostoma morsei	Morse's little plain brown sedge		G1G2	Streams	Ground water
Leuctra mitchellensis	A stonefly		G3	Streams	Ground water
Leuctra szczytkoi	Schoolhouse Springs leuctran stonefly		G2	Streams	Ground water
Ochrotrichia okaloosa	A caddisfly		G1	Streams	Ground water
Ochrotrichia provosti	Provost's ochrotrichian caddisfly		G1	Streams	Ground water
Libellula jesseana	Purple skimmer		G2	Lakes	Lakes
Libellula composita	Bleached skimmer		G3	Ground water	Ponds
Nehalennia pallidula	Everglades sprite		G3	Ponds	Ponds
Gomphus diminutus	Diminutive clubtail		G3	Streams	Ponds
Somatochlora calverti	Calvert's emerald		G3	Streams	Ponds
Somatochlora margarita	Texas emerald		G2	Streams	Ponds
Oxyethira kingi	King's cream and brown mottled microcaddis		G1	Lakes	Rivers
Acanthametropus pecatonica	Pecatonica River mayfly		G2	Rivers	Rivers
Acroneuria petersi	A stonefly		G3	Rivers	Rivers
Allocapnia jeanae	A winter stonefly		G2	Rivers	Rivers
Alloperla ouachita	A stonefly		G2	Rivers	Rivers
Anepeorus simplex	Wallace's deepwater mayfly		G2	Rivers	Rivers
Diploperla kanawholensis	Little kanawha perlodid stonefly		G3	Rivers	Rivers
Gomphus crassus	Handsome clubtail		G3	Rivers	Rivers
Gomphus gonzalezi	Tamaulipan clubtail		G2	Rivers	Rivers
Gomphus modestus	Gulf Coast clubtail		G3	Rivers	Rivers
Gomphus ventricosus	Skillet clubtail		G3	Rivers	Rivers
Gomphus viridifrons	Green-faced clubtail		G3	Rivers	Rivers
Gomphus westfalli	Westfall's clubtail		G1G2	Rivers	Rivers
Helopicus nalatus	A stonefly		G3	Rivers	Rivers
Heterocloeon berneri	Berner's two-winged mayfly		G1	Rivers	Rivers
Homoeoneuria cahabensis	Cahaba sand-filtering mayfly		G2	Rivers	Rivers
Homoeoneuria dolani	Blue sand-river mayfly		G2	Rivers	Rivers

continued

AQUATIC

Table 23.5—The rare aquatic insects evaluated included 176 species, of which 2 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]
Hydroperla fugitans	A spring stonefly		G3	Rivers	Rivers
Hydroperla phormidia	A stonefly		G3	Rivers	Rivers
Macromia margarita	Mountain River cruiser		G3	Rivers	Rivers
Ophiogomphus acuminatus	Acuminate snaketail		G2	Rivers	Rivers
Ophiogomphus edmundo	Edmund's snaketail		G1	Rivers	Rivers
Ophiogomphus howei	Pygmy snaketail		G3	Rivers	Rivers
Ophiogomphus incurvatus	Appalachian snaketail		G3	Rivers	Rivers
Ophiogomphus incurvatus incurvatus			G3T3	Rivers	Rivers
Ophiogomphus westfalli	Westfall's snaketail		G2	Rivers	Rivers
Orthotrichia dentata	Dentate orthotrichian microcaddis		G1G2	Rivers	Rivers
Pentagenia robusta	Robust pentagenian burrowing mayfly		GX	Rivers	Rivers
Protoptila arca	San Marcos saddle-case caddisfly		G1	Rivers	Rivers
Pteronarcys comstocki	A stonefly		G3	Rivers	Rivers
Remenus duffieldi	A stonefly		G2	Rivers	Rivers
Somatochlora ozarkensis	Ozark emerald		G3	Rivers	Rivers
Stylurus notatus	Elusive clubtail		G3	Rivers	Rivers
Stylurus potulentus	Yellow-sided clubtail		G2	Rivers	Rivers
Stylurus townesi	Townes' clubtail		G3	Rivers	Rivers
Taeniopteryx robinae	A stonefly		G1	Rivers	Rivers
Taeniopteryx starki	Leoan River winter stonefly		G1	Rivers	Rivers
Traverella lewisi	A mayfly		G2	Rivers	Rivers
Erpetogomphus heterodon	Dashed ringtail		G3	Streams	Rivers
Gomphus hodgesi	Hodges' clubtail		G3	Streams	Rivers
Oecetis morsei	Morse's long-horn sedge		G2	Streams	Rivers
Ophiogomphus australis	Southern snaketail		G2	Streams	Rivers
Stylurus potulentus	Yellow-sided clubtail		G2	Streams	Rivers
Hansonoperla cheaha	A stonefly		G2	Ground water	Streams
Hydroptila chelops	A caddisfly		G1	Ground water	Streams
Hydroptila decia	Knoxville hydroptilan micro caddisfly		G1G3	Ground water	Streams
Hydroptila lagoi	A caddisfly		G1	Ground water	Streams
Leuctra nephophila	A stonefly		G3	Ground water	Streams
Prostoia hallasi	Hallas' broadback spring stonefly		G3	Ground water	Streams
Remenus kirchneri	A stonefly		G2	Ground water	Streams
Progomphus bellei	Belle's sanddragon		G3	Ponds	Streams
Isonychia berneri	A mayfly		G3	Rivers	Streams
Orthotrichia instabilis	Changeable orthotrichian microcaddis		G1G3	Rivers	Streams
Perlesta browni	A stonefly		G3	Rivers	Streams
Acroneuria flinti	Flint's common stonefly		GH	Streams	Streams
Acroneuria hitchcocki	A stonefly		G3	Streams	Streams
Acroneuria ozarkensis	A perlid stonefly		G2	Streams	Streams
Agarodes alabamensis	A caddisfly		G1	Streams	Streams
Allocapnia fumosa	A stonefly		G2	Streams	Streams
Allocapnia illinoensis	A stonefly		G3	Streams	Streams
Allocapnia oribata	A stonefly		G1	Streams	Streams
Allocapnia ozarkana	A winter stonefly		G2	Streams	Streams
Allocapnia peltoides	A stonefly		G3	Streams	Streams
Allocapnia perplexa	A stonefly		G1	Streams	Streams
Allocapnia stannardi	A stonefly		G3	Streams	Streams
Allocapnia tennessa	A stonefly		G3	Streams	Streams
Allocapnia warreni	A winter stonefly		GH	Streams	Streams

continued

Table 23.5—The rare aquatic insects evaluated included 176 species, of which 2 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]
Alloperla biserrata	A stonefly		G3	Streams	Streams
Alloperla caddo	A stonefly		G2	Streams	Streams
Alloperla furcula	A stonefly		G2	Streams	Streams
Alloperla natchez	Natchez stonefly		G2	Streams	Streams
Amphinemura mockfordi	A stonefly		G2	Streams	Streams
Argia pima	Pima dancer		G1G3	Streams	Streams
Argia rhoadsi	Golden-winged dancer		G3	Streams	Streams
Baetisca becki	A mayfly		G2	Streams	Streams
Beloneuria georgiana	Georgia beloneurian stonefly		G2	Streams	Streams
Beloneuria jamesae	Cheaha beloneurian stonefly		G1	Streams	Streams
Beloneuria stewarti	Cheaha beloneurian stonefly		G3	Streams	Streams
Ceraclea alabamae	A caddisfly		G1	Streams	Streams
Cheumatopsyche bibbensis	A caddisfly		G1	Streams	Streams
Cheumatopsyche cahaba	A caddisfly		G1	Streams	Streams
Cheumatopsyche gordonae	Gordon's little sister sedge		G1	Streams	Streams
Cheumatopsyche helma	Helma's net-spinning caddisfly		G1G3	Streams	Streams
Cheumatopsyche petersi	Peters' cheumatopsyche caddisfly		G2	Streams	Streams
Diploperla morgani	A stonefly		G2	Streams	Streams
Gomphus geminatus	Twin-striped clubtail		G3	Streams	Streams
Gomphus sandrius	Tennessee clubtail		G1	Streams	Streams
Habrophlebiodes annulata	A mayfly		G2	Streams	Streams
Hansonoperla appalachia	Hanson's Appalachian stonefly		G3	Streams	Streams
Hansonoperla hokolesqua	A stonefly		G2	Streams	Streams
Haploperla chukcho	Chukcho stonefly		G2	Streams	Streams
Helopicus bogaloosa	A stonefly		G3	Streams	Streams
Hydroperla rickeri	A stonefly		G2	Streams	Streams
Hydropsyche alabama	A caddisfly		G1	Streams	Streams
Hydroptila berneri	Berner's microcaddisfly		G1	Streams	Streams
Hydroptila cheaha	A caddisfly		G1	Streams	Streams
Hydroptila choccolocco	A caddisfly		G1	Streams	Streams
Hydroptila fuscina	A caddisfly		G1	Streams	Streams
Hydroptila lloganae	Llogan's varicolored microcaddisfly		G1G3	Streams	Streams
Hydroptila metteei	A caddisfly		G1	Streams	Streams
Hydroptila micropotamis	A caddisfly		G1	Streams	Streams
Hydroptila molsonae	Molson's microcaddisfly		G2G3	Streams	Streams
Hydroptila paralatosa	A caddisfly		G2	Streams	Streams
Hydroptila patriciae	A caddisfly		G1	Streams	Streams
Hydroptila scheiringi	A caddisfly		G1	Streams	Streams
Hydroptila setigera	A caddisfly		G1	Streams	Streams
Hydroptila wetumpka	A caddisfly		G1	Streams	Streams
Isoperla distincta	A stonefly		G3	Streams	Streams
Isoperla ouachita	A stonefly		G3	Streams	Streams
Leuctra moha	A stonefly		G3	Streams	Streams
Leuctra paleo	A stonefly		G2	Streams	Streams
Macdunnoa brunnea	A mayfly		G3	Streams	Streams
Neochoroterpes kossi	A mayfly		G2	Streams	Streams
Neoperla harrisi	Perlid stonfly		G2	Streams	Streams
Nyctiophylax morsei	Morse's dinky light summer sedge		G1G2	Streams	Streams
Ochrotrichia elongiralla	A caddisfly		G1	Streams	Streams
Oecetis daytona	A caddisfly		G2	Streams	Streams
Oecetis parva	Little oecetis longhorn caddisfly		GH	Streams	Streams
Oxyethira kellyi	Kelly's cream and brown mottled microcaddis		G1G2	Streams	Streams
Oxyethira lumipollex	A caddisfly		G2	Streams	Streams

continued

AQUATIC

Table 23.5—The rare aquatic insects evaluated included 176 species, of which 2 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]
Oxyethira novasota	Novaaota oxyethiran microcaddisfly		G2	Streams	Streams
Perlesta baumanni	A stonefly		G2	Streams	Streams
Perlesta bolukta	A stonefly		G2	Streams	Streams
Perlesta frisoni	A stonefly		G3	Streams	Streams
Phylocentropus harrisi	A caddisfly		G1	Streams	Streams
Polycentropus carlsoni	Carlson's polycentropus caddisfly		G1G3	Streams	Streams
Polycentropus floridensis	Florida brown checkered summer sedge		G2	Streams	Streams
Protoptila cahabensis	Cahaba saddle-case caddisfly		G1	Streams	Streams
Rhyacophila alabama	A caddisfly		G1	Streams	Streams
Rhyacophila carolae	A caddisfly		G1	Streams	Streams
Serratella frisoni	Frison's serratellan mayfly		G3	Streams	Streams
Serratella spiculosa	Spiculose serratellan mayfly		G2	Streams	Streams
Siphloplecton brunneum	A mayfly		G1	Streams	Streams
Stactobiella cahaba	A caddisfly		G1	Streams	Streams
Taeniopteryx nelsoni	Nelson's early black stonefly		G1	Streams	Streams
Tallaperla elisa	A stonefly		G3	Streams	Streams
Tallaperla lobata	Lobed roach-like stonefly		G2	Streams	Streams
Theliopsyche tallapoosa	A caddisfly		G1	Streams	Streams
Triaenodes helo	Marsh triaenode caddisfly		G2G3	Streams	Streams
Triaenodes tridonta	Three-toothed triaenodes caddisfly		GH	Streams	Streams
Zealeuctra arnoldi	A stonefly		G3	Streams	Streams
Zealeuctra wachita	A stonefly		G2	Streams	Streams

ABI = Association for Biodiversity Information.
[a] Federal status: LE = listed as endangered; C = candidate for listing.
[b] See table 23.1 for definitions of ABI rankings.
[c] Primary and secondary habitat do not necessarily imply a consistant order or ranking of importance to the taxonomic group.
Source: NatureServe 2001b.

Although biological threats are not listed for the beetles, the USFWS (U.S. Federal Register 1997) stated, "The primary factor threatening the long-term survival of these species is availability of a sufficient quantity of water to maintain essential characteristics of their habitat."

Factors that can affect aquatic insects in general include runoff, including sediment and chemicals from agricultural, silvicultural, and urban activities. Other threats include water-quality degradation from fish farms, and exotic pests that affect trees on streamsides. Forest harvests also can produce other changes that could affect stream-dwelling insects. For example, a change in plant community composition may reduce the amount of large woody debris in streams, a change in the processing rate of organic matter, or lowered quality of food (leaves) that falls into the stream to be "processed" by insects (Morse and others 1997). These changes could affect the entire food web.

Future for insects—The riverine insects have lost a considerable amount of habitat as a result of dams and reservoirs. The remaining populations are often isolated from each other by great distances, making dispersal and genetic exchange difficult or impossible. Some intervening habitats, which may be suitable, are unoccupied for unknown reasons. Three odonate species are restricted to single populations, and the loss of any of these populations would amount to extinction of the species. Better information about the distribution of all rare odonates is needed. To ensure long-term viability of all stream-dwelling insects, measures that improve and maintain water and habitat quality are needed.

The insects restricted to springs and other ground-water habitats are threatened by water withdrawal that dewaters the aquifers, by pollutants (that can become concentrated as ground water is lowered), and by other activities that directly affect spring habitats.

Snails—The 123 freshwater snails (table 23.6) (fig. 23.8) included in this Assessment are classified into two groups: Pulmonata (7 species) and Prosobranchia (116 species) (Hart and Fuller 1974). Members of the order Pulmonata are related to terrestrial snails and are capable of breathing air, which allows them to exist in water containing low levels of oxygen (Hart and Fuller 1974). Five of these, including one lake dweller and two stream dwellers, are presumed to be extinct. The two remaining species are known from swift-flowing water (Hart and Fuller 1974).

Table 23.6—The rare aquatic snails evaluated included 123 species, of which 11 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Subclass
Amnicola cora	Foushee cavesnail		G1	Ground water	Ground water	Prosobranchia
Antroselatus spiralis	Shaggy cavesnail		G2G3	Ground water	Ground water	Prosobranchia
Aphaostracon asthenes	Blue spring hydrobe		G1	Ground water	Ground water	Prosobranchia
Aphaostracon chalarogyrus	Freemouth hydrobe		G1	Ground water	Ground water	Prosobranchia
Aphaostracon monas	Wekiwa hydrobe		G1	Ground water	Rivers	Prosobranchia
Aphaostracon pycnus	Dense hydrobe		G1	Ground water	Ground water	Prosobranchia
Aphaostracon theiocrenetus	Clifton spring hydrobe		G1	Ground water	Ground water	Prosobranchia
Aphaostracon xynoelictus	Fenney spring hydrobe		G1	Ground water	Ground water	Prosobranchia
Campeloma decampi	Slender campeloma	LE	G1	Streams	Streams	Prosobranchia
Cincinnatia helicogyra	Crystal siltsnail		G1	Ground water	Ground water	Prosobranchia
Cincinnatia integra	Midland siltsnail		G3	Rivers	Rivers	Prosobranchia
Cincinnatia mica	Ichetucknee siltsnail		G1	Ground water	Ground water	Prosobranchia
Cincinnatia monroensis	Enterprise siltsnail		G1	Ground water	Streams	Prosobranchia
Cincinnatia parva	Pygmy siltsnail		GX	Ground water	Ground water	Prosobranchia
Cincinnatia ponderosa	Ponderous siltsnail		G1	Ground water	Ground water	Prosobranchia
Cincinnatia vanhyningi	Seminole siltsnail		G1	Ground water	Ground water	Prosobranchia
Cincinnatia wekiwae	Wekiwa siltsnail		G1	Ground water	Ground water	Prosobranchia
Clappia cahabensis	Cahaba pebblesnail		GH	Rivers	Rivers	Prosobranchia
Clappia umbilicata	Umbilicate pebblesnail		GH	Rivers	Rivers	Prosobranchia
Dasyscias franzi	Shaggy ghostsnail		G1	Ground water	Ground water	Prosobranchia
Elimia acuta	Acute elimia		G1	Rivers	Rivers	Prosobranchia
Elimia alabamensis	Mud elimia		G1	Rivers	Streams	Prosobranchia
Elimia ampla	Ample elimia		G1	Rivers	Rivers	Prosobranchia
Elimia aterina	Coal elimia		G1	Streams	Streams	Prosobranchia
Elimia bellacrenata	Princess elimia		G1	Ground water	Streams	Prosobranchia
Elimia bellula	Walnut elimia		G1	Rivers	Streams	Prosobranchia
Elimia bentoniensis	Rusty elimia		G1	Streams	Streams	Prosobranchia
Elimia brevis	Short-spire elimia		GH	Rivers	Rivers	Prosobranchia
Elimia cahawbensis	Cahaba elimia		G3	Streams	Streams	Prosobranchia
Elimia capillaris	Spindle elimia		G1	Rivers	Rivers	Prosobranchia
Elimia chiltonensis	Prune elimia		G1	Streams	Streams	Prosobranchia
Elimia clara	Riffle elimia		G3	Rivers	Rivers	Prosobranchia
Elimia clausa	Closed elimia		GH	Rivers	Rivers	Prosobranchia
Elimia clenchi	Slackwater elimia		G1G2	Rivers	Rivers	Prosobranchia
Elimia cochilaris	Cockle elimia		G1	Ground water	Streams	Prosobranchia
Elimia crenatella	Lacey elimia	LT	G1	Rivers	Streams	Prosobranchia
Elimia cylindracea	Cylinder elimia		G1	Rivers	Rivers	Prosobranchia
Elimia fusiformis	Fusiform elimia		GH	Rivers	Rivers	Prosobranchia
Elimia gibbera			GH	Rivers	Rivers	Prosobranchia
Elimia hartmaniana	High-spired elimia		GH	Rivers	Rivers	Prosobranchia
Elimia haysiana	Silt elimia		G1	Rivers	Rivers	Prosobranchia
Elimia hydei	Gladiator elimia		G2	Rivers	Rivers	Prosobranchia
Elimia impressa	Constricted elimia		GH	Rivers	Rivers	Prosobranchia
Elimia jonesi	Hearty elimia		GH	Rivers	Rivers	Prosobranchia
Elimia lachryma	Nodulose Coosa River snail (AL)		GH	Rivers	Rivers	Prosobranchia
Elimia laeta	Ribbed elimia		GH	Rivers	Rivers	Prosobranchia
Elimia macglameriana	Macglamery's Coosa River snail (AL)		GH	Rivers	Rivers	Prosobranchia
Elimia pilsbryi	Rough-lined elimia		GH	Rivers	Rivers	Prosobranchia
Elimia pupaeformis	Pupa elimia		GH	Rivers	Rivers	Prosobranchia
Elimia vanuxemiana	Cobble elimia		GH	Rivers	Rivers	Prosobranchia
Fontigens orolibas	Blue Ridge springsnail		G2G3	Ground water	Ground water	Prosobranchia
Gyrotoma excisa	Excised slitshell		GX	Rivers	Rivers	Prosobranchia
Gyrotoma lewisii	Striate slitshell		GX	Rivers	Rivers	Prosobranchia
Gyrotoma pagoda	Pagoda slitshell		GX	Rivers	Rivers	Prosobranchia
Gyrotoma pumila	Ribbed slitshell		GX	Rivers	Rivers	Prosobranchia
Gyrotoma pyramidata	Pyramid slitshell		GX	Rivers	Rivers	Prosobranchia
Gyrotoma walkeri	Round slitshell		GX	Rivers	Rivers	Prosobranchia
Io fluvialis	Spiny riversnail		G2	Rivers	Rivers	Prosobranchia
Leptoxis ampla	Round rocksnail	LT	G1G2	Rivers	Rivers	Prosobranchia
Leptoxis clipeata	Agate rocksnail		GH	Rivers	Rivers	Prosobranchia
Leptoxis compacta	Oblong rocksnail		GH	Rivers	Streams	Prosobranchia
Leptoxis crassa	Boulder snail		GH	Rivers	Rivers	Prosobranchia
Leptoxis crassa anthonyi	Anthony's river snail	LE	G1T1	Rivers	Rivers	Prosobranchia
Leptoxis formanii	Interrupted rocksnail		G1	Rivers	Rivers	Prosobranchia

continued

AQUATIC

Table 23.6—The rare aquatic snails evaluated included 123 species, of which 11 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Subclass
Leptoxis formosa	Maiden rocksnail		GH	Streams	Streams	Prosobranchia
Leptoxis ligata	Rotund rocksnail		GH	Rivers	Rivers	Prosobranchia
Leptoxis lirata	Lirate rocksnail		GH	Rivers	Rivers	Prosobranchia
Leptoxis melanoidus	Black mudalia		G2	Rivers	Rivers	Prosobranchia
Leptoxis occultata	Bigmouth rocksnail		GH	Rivers	Rivers	Prosobranchia
Leptoxis picta	Spotted rocksnail		G1	Rivers	Rivers	Prosobranchia
Leptoxis plicata	Plicate rocksnail	LE	G1	Streams	Rivers	Prosobranchia
Leptoxis showalterii	Coosa rocksnail		GH	Rivers	Rivers	Prosobranchia
Leptoxis taeniata	Painted rocksnail	LT	G1	Rivers	Rivers	Prosobranchia
Leptoxis umbilicata	Umbilicate rocksnail		G1	Rivers	Rivers	Prosobranchia
Leptoxis virgata	Smooth mudalia		G2	Rivers	Rivers	Prosobranchia
Leptoxis vittata	Striped rocksnail		GH	Rivers	Rivers	Prosobranchia
Lepyrium showalteri	Flat pebblesnail	LE	G1	Rivers	Rivers	Prosobranchia
Lioplax cyclostomaformis	Cylindrical lioplax	LE	G1	Rivers	Rivers	Prosobranchia
Lithasia duttoniana	Helmet rocksnail		G2	Rivers	Streams	Prosobranchia
Lithasia jayana	Rugose rocksnail		G2	Rivers	Rivers	Prosobranchia
Lithasia lima	Warty rocksnail		G2	Rivers	Rivers	Prosobranchia
Phreatodrobia imitata	Mimic cavesnail		G1	Ground water	Ground water	Prosobranchia
Pleurocera annulifera	Ringed hornsnail		G1	Rivers	Streams	Prosobranchia
Pleurocera brumbyi	Spiral hornsnail		G1	Ground water	Streams	Prosobranchia
Pleurocera corpulenta	Corpulent hornsnail		G1	Rivers	Rivers	Prosobranchia
Pleurocera curta	Shortspire hornsnail		G2	Rivers	Rivers	Prosobranchia
Pleurocera postelli	Broken hornsnail		G2	Streams	Streams	Prosobranchia
Pleurocera pyrenella	Skirted hornsnail		G2	Rivers	Rivers	Prosobranchia
Pleurocera trochiformis	Sulcate hornsnail		G2	Rivers	Rivers	Prosobranchia
Pyrgulopsis agarhecta	Ocmulgee marstonia		G1	Streams	Streams	Prosobranchia
Pyrgulopsis castor	Beaverpond marstonia		G1	Streams	Streams	Prosobranchia
Pyrgulopsis davisi	Limpia creek springsnail		G1	Ground water	Streams	Prosobranchia
Pyrgulopsis metcalfi	Naegele springsnail		G1	Ground water	Ground water	Prosobranchia
Pyrgulopsis ogmorhaphe	Royal marstonia	LE	G1	Ground water	Streams	Prosobranchia
Pyrgulopsis olivacea	Olive marstonia		GH	Streams	Ground water	Prosobranchia
Pyrgulopsis ozarkensis	Ozark pyrg		G1	Rivers	Rivers	Prosobranchia
Pyrgulopsis pachyta	Armored marstonia	LE	G1	Streams	Streams	Prosobranchia
Pyrgulopsis scalariformis	Moss pyrg		G1	Rivers	Rivers	Prosobranchia
Somatogyrus amnicoloides	Ouachita pebblesnail		GX	Rivers	Rivers	Prosobranchia
Somatogyrus biangulatus	Angular pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus crassilabris	Thicklipped pebblesnail		GX	Rivers	Rivers	Prosobranchia
Somatogyrus currierianus	Tennessee pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus excavatus	Ovate pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus humerosus	Atlas pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus quadratus	Quadrate pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus strengi	Rolling pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus substriatus	Choctaw pebblesnail		GH	Rivers	Rivers	Prosobranchia
Somatogyrus tenax	Savannah pebblesnail		G2G3	Rivers	Rivers	Prosobranchia
Somatogyrus tennesseensis	Opaque pebblesnail		G1	Rivers	Rivers	Prosobranchia
Somatogyrus virginicus	Panhandle pebblesnail		G1G2	Rivers	Rivers	Prosobranchia
Somatogyrus wheeleri	Channelled pebblesnail		GX	Rivers	Rivers	Prosobranchia
Stiobia nana	Sculpin snail		G3	Ground water	Streams	Prosobranchia
Tryonia adamantina	Diamond Y spring snail	C	G1	Ground water	Streams	Prosobranchia
Tryonia brunei	Brune spring snail		G1	Ground water	Streams	Prosobranchia
Tryonia cheatumi	Phantom lake tryonia		G1	Streams	Streams	Prosobranchia
Tulotoma magnifica	Tulotoma	LE	G1	Rivers	Rivers	Prosobranchia
Amphigyra alabamensis	Shoal sprite		GH	Rivers	Rivers	Pulmonata
Neoplanorbis smithi	Classification uncertain		GX	Rivers	Rivers	Pulmonata
Neoplanorbis tantillus	Classification uncertain		GX	Rivers	Rivers	Pulmonata
Neoplanorbis umbilicatus	Classification uncertain		GX	Rivers	Rivers	Pulmonata
Planorbella magnifica	Magnificent rams-horn		G1	Ponds	Ponds	Pulmonata
Rhodacme elatior	Domed ancylid		G1	Rivers	Rivers	Pulmonata
Stagnicola neopalustris	Piedmont pondsnail		GX	Ponds	Ponds	Pulmonata

ABI = Association for Biodiversity Information.
[a] Federal status: LE = listed as endangered; LT = listed as threatened; C = candidate for listing.
[b] See table 23.1 for definitions of ABI rankings.
[c] Primary and secondary habitat do not necessarily imply a consistent order or ranking of importance to the taxonomic group.
Source: NatureServe 2000a.

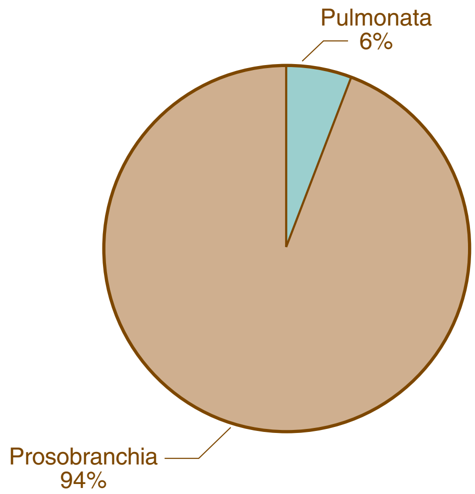


Figure 23.8—The 123 rare aquatic snail species are separated into 2 groups based on their mode of respiration. The Pulmonata have a "lung" and are able to breathe air while the Prosobranchia have gills.

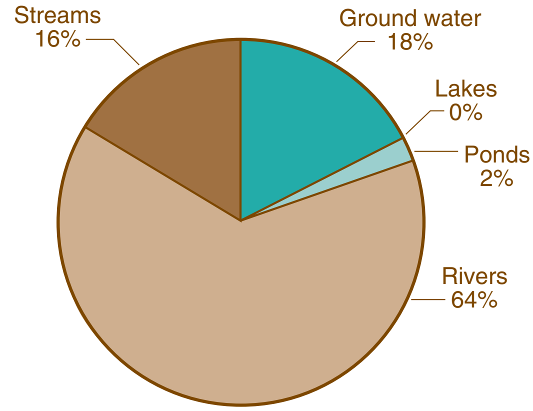


Figure 23.9—The 123 rare snails are found in 4 of the 5 aquatic habitats evaluated. Lakes are not used at all and ponds are a minor habitat.

Members of the order Prosobranchia are related to marine snails and have internal gills that help them obtain oxygen from the water (Hart and Fuller 1974). All 22 of the spring or cave species and 94 of the stream-dwelling snails belong to this group. Figure 23.9 displays the habitats utilized by rare snail species.

Snails feed on algae and detritus, which are scraped from rocks, vegetation, and other substrates (Pennak 1989). Life cycles typically range from 1 to 3 years; most species have annual life cycles (Pennak 1989). Reproduction varies among species. The majority of species are egg layers, but some are live-bearers (Hart and Fuller 1974).

The distribution of rare aquatic snails is highly localized; most of the stream-dwelling snails are indigenous to the Tennessee or Mobile River systems (fig. 23.10). One rare species is found in lakes in Virginia. Others are known from springs and caves: 14 species in Florida, 3 in Texas, 2 in Kentucky, and 1 each in Arkansas, Virginia, and Alabama.

Threats to snails—Threats to the viability of these rare snails are associated with impacts to their preferred habitats. For example, the Piedmont pondsnail was known from only one pond. It apparently became extinct because cattle were allowed access to the pond for watering (NatureServe 2000).

Many of the 100 stream-dependent snail species are historically known from small geographic areas, even single riffles, and therefore have been threatened by dams. For example, a series of dams on the Coosa River is believed to have caused the immediate extinction of at least 20 snail species (Lydeard and Mayden 1995). Any existing populations of these stream-dwelling snails are physically isolated by reservoirs (U.S. Department of the Interior, Fish and Wildlife Service 2000). At least 89 of the 100 rare snails that prefer streams are concentrated in the Tennessee and Mobile River systems (fig. 23.10). In North America, at least 36 species of snails are thought to have become extinct since European settlement began; all are from the Mobile River system (Lydeard and Mayden 1995). Exotic species, including zebra mussels, are threats to the remaining stream-dwelling populations of rare snails (Hart and Fuller 1974).

A major threat is sedimentation. It can inhibit growth of algae on which snails graze (Neves and others 1997), accelerate erosion of snail shells, and affect survival of eggs (Hart and Fuller 1974). Although scant information on toxicity is available, other pollution events, such as chemical spills, are potential threats to aquatic gastropods (Hart and Fuller 1974, Neves and others 1997).

Future for snails—The single lake-dwelling snail species listed in this Assessment is considered extinct. The narrowly endemic Piedmont pondsnail was apparently formerly restricted to a single lake. It appears to have been destroyed by cattle (NatureServe 2000), but water pollution, sedimentation, or an accidental spill could have produced the same result.

Fourteen of the 22 rare snails associated with springs and caves are found in Florida. All of these species are narrow endemics, often restricted to a single spring (NatureServe 2000). In Florida, the major threats to spring and cave systems are sewage seepage and sedimentation (Petranka 1998). Presently, aquifer drawdown is apparently not a significant threat to the Florida spring systems, but in Texas, it may be the single most important threat (NatureServe 2000). As with all narrow endemics, the magnitude of potential threats to a single population needs to be respected.

Mussels—The 191 rare mussels (table 23.7) evaluated are not divided into subgroups based on taxonomy. They use only river and stream habitats (fig. 23.11). The primary and secondary habitats of each mussel were determined from distribution records and specific references (Dennis 1985; NatureServe 2001; Parmalee and Bogan 1998; U.S. Department of the Interior, Fish and Wildlife Service 1992, 2000; Williams and others 1993). No rare mussels were found to be dependent on ground-water habitats, lakes, or ponds.

Freshwater mussels respire and feed by siphoning water across their gills; food consists of microorganisms and organic particles (Parmalee and Bogan 1998).

Reproduction is extraordinarily complex. Males release sperm into the

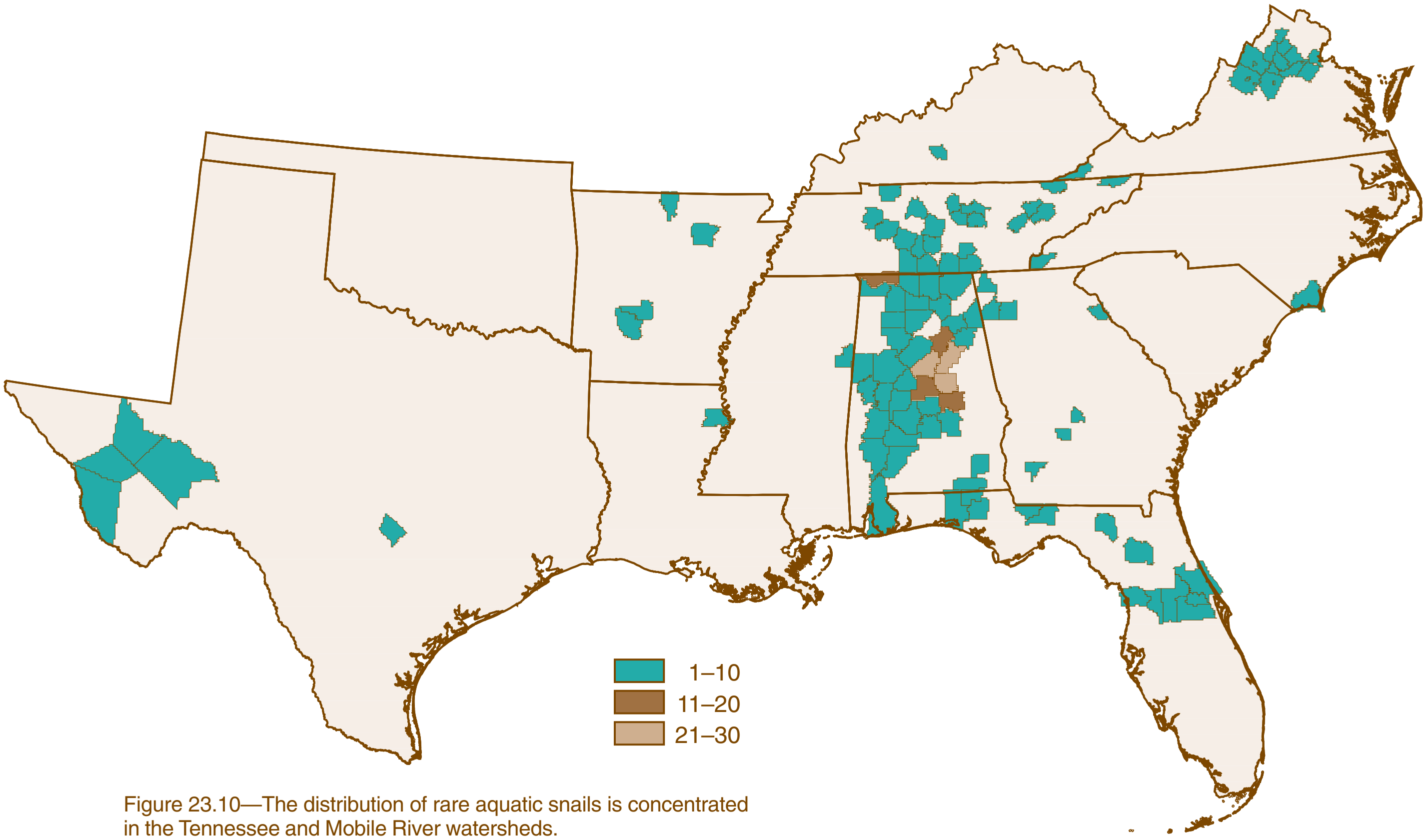


Figure 23.10—The distribution of rare aquatic snails is concentrated in the Tennessee and Mobile River watersheds.

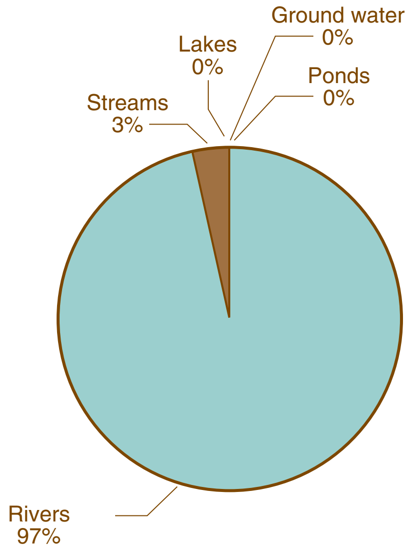


Figure 23.11—The 191 rare mussels are almost completely restricted to rivers. A few are found in streams, but none are dependent on ground water, lakes, or pond systems.

stream; sperm are siphoned out, and fertilization occurs within the females. The eggs mature into larvae known as glochidia, which are released into the water and become encysted on a fish host that is often very specific. Varieties of mechanisms have been developed to ensure that the glochidia reach the appropriate host (Parmalee and Bogan 1998). While parasitizing the fish host, the glochidium transforms into a juvenile mussel. After detaching from the fish, the juvenile mussels take up residence in the stream bottom.

The rare mussels are distributed among 11 major watersheds or groups of watersheds spread across the South (fig. 23.12). This grouping is based on the unionid faunal provinces summarized in Parmalee and Bogan (1998). Almost 80 percent (148 of 191 species) of these rare mussels are endemic to single watersheds.

The Cumberland watershed is home to 60 of the 191 rare mussels evaluated in this Assessment. Historically, the Tennessee and Cumberland River systems had the most diverse mussel fauna in the South (Hughes and Parmalee 1999, Parmalee and Bogan 1998). Although inhabitants of shallow shoals in larger rivers have probably declined the most (Neves and others 1997), some species remain in scattered localities where riverine habitat remains, but they are isolated by dams and reservoirs (Parmalee and Bogan 1998).

Another important area for mussels is the Mobile River basin, which ranks among the top 10 river basins in the World in terms of historical diversity of freshwater mussels (Lydeard and Mayden 1995, U.S. Department of the Interior, Fish and Wildlife Service 2000). Today these imperiled species are found in relatively clean river reaches isolated by degraded reaches or reservoirs (U.S. Department of the Interior, Fish and Wildlife Service 2000).

Table 23.7—The rare mussels evaluated included 191 species, of which 71 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Alasmidonta arcula	Cumberland elktoe		G2	Rivers	Rivers	SA
Alasmidonta atropurpurea	Cumberland elktoe	LE	G1G2	Rivers	Rivers	Cu
Alasmidonta heterodon	Dwarf wedgemussel	LE	G1G2	Rivers	Rivers	NA,SA
Alasmidonta mccordi	Coosa elktoe		GX	Rivers	Rivers	Mo
Alasmidonta raveneliana	Appalachian elktoe	LE	G1	Rivers	Rivers	Cu
Alasmidonta robusta	Carolina elktoe		GX	Rivers	Rivers	SA
Alasmidonta varicosa	Brook floater		G3	Rivers	Rivers	NA,SA
Alasmidonta wrightiana	Ochloskonee arcmussel		GH	Rivers	Rivers	Ap
Amblema elliottii	Coosa fiveridge		G3	Rivers	Rivers	Mo
Amblema neislerii	Fat threeridge	LE	G1	Rivers	Rivers	Ap
Anodonta heardi	Apalachicola floater		G1	Rivers	Rivers	Ap
Anodontoides denigratus	Cumberland papershell		G1	Rivers	Rivers	Cu
Anodontoides radiatus	Rayed creekshell		G3	Rivers	Rivers	Ap,Mo
Arkansia wheeleri	Ouachita rock pocketbook	LE	G1	Rivers	Rivers	Ms,Oz
Cumberlandia monodonta	Spectaclecase		G2G3	Rivers	Rivers	Cu
Cyprogenia aberti	Western fanshell		G2	Rivers	Rivers	Oz
Cyprogenia stegaria	Fanshell	LE	G1	Rivers	Rivers	Cu,Ms
Disconaias salinasensis	Salina mucket		G1	Rivers	Rivers	RG
Dromus dromas	Dromedary pearlymussel	LE	G1	Rivers	Rivers	Cu
Elliptio ahenea	Southern lance		G3	Rivers	Rivers	Fl
Elliptio chipolaensis	Chipola slabshell	LT	G1	Rivers	Rivers	Ap
Elliptio dariensis	Georgia elephantear		G3	Rivers	Rivers	Fl,SA
Elliptio downiei	Satilla elephantear		G3	Rivers	Rivers	SA
Elliptio fraterna	Brother spile		G1	Rivers	Rivers	Ap
Elliptio hepatica	Brown elliptio		G2G3	Rivers	Rivers	SA
Elliptio hopetonensis	Altamaha slabshell		G3	Rivers	Rivers	SA
Elliptio lanceolata	Yellow lance		G2G3	Rivers	Rivers	Ap,NA,SA
Elliptio mcmichaeli	Fluted elephantear		G3	Rivers	Rivers	Ap,Mo
Elliptio monroensis	St. John's elephantear		G2G3	Rivers	Rivers	Fl
Elliptio nigella	Winged spike		GH	Rivers	Rivers	Ap
Elliptio purpurella	Inflated spike		G3	Rivers	Rivers	Ap
Elliptio roanokensis	Roanoke slabshell		G2G3	Rivers	Rivers	SA
Elliptio spinosa	Altamaha spinymussel		G1G2	Rivers	Rivers	SA
Elliptio steinstansana	Tar River spinymussel	LE	G1	Rivers	Rivers	SA
Elliptoideus sloatianus	Purple bankclimber	LT	G2	Rivers	Rivers	Ap
Epioblasma arcaeformis	Sugarspoon		GX	Rivers	Rivers	Cu
Epioblasma biemarginata	Angled riffleshell		GX	Rivers	Rivers	Cu
Epioblasma brevidens	Cumberlandian combshell	LE	G1	Rivers	Rivers	Cu
Epioblasma capsaeformis	Oyster mussel	LE	G1	Rivers	Rivers	Cu
Epioblasma cincinnatiensis	A freshwater mussel		GX	Rivers	Rivers	Ms
Epioblasma flexuosa	Leafshell		GX	Rivers	Rivers	Ms
Epioblasma florentina	Yellow blossom	LE	G1	Rivers	Rivers	Cu
Epioblasma florentina curtisi	Curtis pearlymussel	LE	G1T1	Rivers	Rivers	Cu
Epioblasma florentina florentina	Yellow blossom	LE	G1TX	Rivers	Rivers	Cu
Epioblasma haysiana	Acornshell		GX	Rivers	Rivers	Cu
Epioblasma lenoir	Narrow catspaw		GX	Rivers	Rivers	Cu
Epioblasma lewisii	Forkshell		GX	Rivers	Rivers	Cu
Epioblasma metastriata	Upland combshell	LE	GH	Rivers	Rivers	Mo
Epioblasma obliquata	Catspaw	LE	G1	Rivers	Rivers	Ms
Epioblasma obliquata obliquata	Catspaw	LE	G1T1	Rivers	Rivers	Cu,Ms
Epioblasma obliquata perobliqua	White catspaw	LE	G1T1	Rivers	Rivers	Ms
Epioblasma penita	Southern combshell	LE	G1	Rivers	Rivers	Mo
Epioblasma personata	Round combshell		GX	Rivers	Rivers	Ms
Epioblasma propingua	Tennessee riffleshell		GX	Rivers	Rivers	Cu
Epioblasma sampsonii	Wabash riffleshell	LE	G1	Rivers	Rivers	Ms
Epioblasma stewardsoni	Cumberland leafshell		GX	Rivers	Rivers	Cu
Epioblasma torulosa	Tubercled blossom	LE	G2	Rivers	Rivers	Ms
Epioblasma torulosa gubernaculums	Green blossom	LE	G2TX	Rivers	Rivers	Ms

continued

AQUATIC

Table 23.7—The rare mussels evaluated included 191 species, of which 71 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Epioblasma torulosa rangiana	Northern riffleshell	LE	G2T2	Rivers	Rivers	Ms
Epioblasma torulosa torulosa	Tubercled blossom	LE	G2TX	Rivers	Rivers	Ms
Epioblasma triquetra	Snuffbox		G3	Rivers	Rivers	Cu,Ms
Epioblasma turgidula	Turgid blossom	LE	GH	Rivers	Rivers	Cu
Fusconaia apalachicola	Apalachicola ebonyshell		GX	Rivers	Rivers	Ap
Fusconaia askewi	Tesas pigtoe		G2	Rivers	Rivers	Ms,Sab
Fusconaia cor	Shiny pigtoe	LE	G1	Rivers	Rivers	Mo
Fusconaia cuneolus	Finerayed pigtoe	LE	G1	Rivers	Rivers	Cu
Fusconaia escambia	Narrow pigtoe		G2	Rivers	Rivers	Ap
Fusconaia masoni	Atlantic pigtoe		G2	Rivers	Rivers	SA
Fusconaia ozarkensis	Ozark pigtoe		G3	Rivers	Rivers	Ms
Fusconaia subrotunda	Longsolid		G3	Rivers	Rivers	Cu,Ms
Fusconaia subrotunda subrotunda	Longsolid		G3T3	Rivers	Rivers	Cu,Ms
Fusconaia succissa	Purple pigtoe		G3	Rivers	Rivers	Ap
Hemistena lata	Cracking pearlymussel	LE	G1	Rivers	Rivers	Cu,Ms
Lampsilis abrupta	Pink mucket	LE	G2	Rivers	Rivers	Cu,Ms
Lampsilis altilis	Finelined pocketbook	LT	G2	Rivers	Rivers	Mo
Lampsilis australis	Southern sandshell		G2	Rivers	Rivers	Ap
Lampsilis binominata	Lined pocketbook		GH	Rivers	Rivers	Ap
Lampsilis bracteata	Texas fatmucket		G1	Rivers	Rivers	CT
Lampsilis dolabraeformis	Altamaha pocketbook		G3	Rivers	Rivers	SA
Lampsilis higginsii	Higgins eye	LE	G1	Rivers	Rivers	Ms
Lampsilis perovalis	Orangenacre mucket	LT	G2	Rivers	Rivers	Mo
Lampsilis powellii	Arkansas fatmucket	LT	G1G2	Rivers	Rivers	Ms
Lampsilis rafinesqueana	Neosho mucket		G2	Rivers	Rivers	Oz
Lampsilis reeviana	Arkansas brokenray		G3	Rivers	Rivers	Oz
Lampsilis reeviana brevucula	Ozark brokenray		G3T2	Rivers	Rivers	Oz
Lampsilis reeviana reeviana	Arkansas brokenray		G3T1T2	Rivers	Rivers	Oz
Lampsilis satura	Sandbank pocketbook		G2	Rivers	Rivers	Ms
Lampsilis sp.2	A freshwater mussel		G1	Rivers	Rivers	SA
Lampsilis splendida	Rayed pink fatmucket		G3	Rivers	Rivers	SA
Lampsilis straminea straminea	Rough fatmucket		G5T3	Rivers	Rivers	Mo
Lampsilis subangulata	Shinyrayed pocketbook	LE	G2	Rivers	Rivers	Ap
Lampsilis virescens	Alabama lampmussel	LE	G1	Rivers	Rivers	Cu
Lasmigona complanata alabamensis	Alabama heelsplitter		G5T2T3	Rivers	Rivers	Mo
Lasmigona decorata	Carolina heelsplitter	LE	G1	Rivers	Rivers	SA
Lasmigona subviridis	Green floater		G3	Rivers	Rivers	NA,SA
Lemiox rimosus	Birdwing pearlymussel	LE	G1	Rivers	Rivers	Cu
Leptodea leptodon	Scaleshell	PE	G1	Rivers	Rivers	Cu,Ms
Lexingtonia dolabelloides	Slabside pearlymussel		G2	Rivers	Rivers	Cu
Margaritifera hembeli	Louisiana pearlshell	LT	G1	Rivers	Rivers	Ms,Mo
Margaritifera marrianae	Alabama pearlshell	C	G1	Rivers	Rivers	Mo
Medionidus acutissimus	Alabama moccasinshell	LT	G1	Rivers	Rivers	Mo
Medionidus parvulus	Coosa moccasinshell	LE	G1	Rivers	Rivers	Mo
Medionidus penicillatus	Gulf moccasinshell	LE	G1	Rivers	Rivers	Ap,Fl
Medionidus simpsonianus	Ochlockonee moccasinshell	LE	G1	Rivers	Rivers	Ap
Medionidus walkeri	Suwannee moccasinshell		G1	Rivers	Rivers	Fl
Obovaria jachsoniana	Southern hickorynut		G1G2	Rivers	Rivers	Ms
Obovaria retusa	Ring pink	LE	G1	Rivers	Rivers	Cu,Ms
Obovaria rotulata	Round ebonyshell		G1	Rivers	Rivers	Ap
Obovaria unicolor	Alabama hickorynut		G3	Rivers	Rivers	Ap,Ms
Pegias fabula	Littlewing pearlymussel	LE	G1	Rivers	Rivers	Cu
Plethobasus cicatricosus	White wartyback	LE	G1	Rivers	Rivers	Cu,Ms
Plethobasus cooperianus	Orangefoot pimpleback	LE	G1	Rivers	Rivers	Cu,Ms
Plethobasus cyphyus	Sheepnose		G3	Rivers	Rivers	Cu,Mi
Pleurobema altum	Highnut		GH	Rivers	Rivers	Mo
Pleurobema avellanum	Hazel pigtoe		GH	Rivers	Rivers	Mo
Pleurobema beadleianum	Mississippi pigtoe		G2G3	Rivers	Rivers	Ms
Pleurobema chattanoogaense	Painted clubshell		G1	Rivers	Rivers	Mo
Pleurobema clava	Clubshell	LE	G2	Rivers	Rivers	Cu,Ms

continued

AQUATIC

Table 23.7—The rare mussels evaluated included 191 species, of which 71 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Pleurobema collina	James spinymussel	LE	G1	Rivers	Rivers	SA
Pleurobema cordatum	Ohio pigtoe		G3	Rivers	Rivers	Ms
Pleurobema curtum	Black clubshell	LE	G1	Rivers	Rivers	Mo
Pleurobema decisum	Southern clubshell	LE	G1G2	Rivers	Rivers	Mo
Pleurobema furvum	Dark pigtoe	LE	G1	Rivers	Rivers	Mo
Pleurobema georgianum	Southern pigtoe	LE	G1	Rivers	Rivers	Mo
Pleurobema gibberum	Cumberland pigtoe	LE	G1	Rivers	Rivers	Cu
Pleurobema hagleri	Brown pigtoe		G1	Rivers	Rivers	Mo
Pleurobema hanleyianum	Georgia pigtoe		G1	Rivers	Rivers	Mo
Pleurobema johannis	Alabama pigtoe		GH	Rivers	Rivers	Mo
Pleurobema marshalli	Flat pigtoe	LE	GH	Rivers	Rivers	Mo
Pleurobema murrayense	Coosa pigtoe		GH	Rivers	Rivers	Mo
Pleurobema nucleopsis	Longnut		GH	Rivers	Rivers	Mo
Pleurobema perovatum	Ovate clubshell	LE	G1	Rivers	Rivers	Mo
Pleurobema plenum	Rough pigtoe	LE	G1	Rivers	Rivers	Cu,Ms
Pleurobema pyriforme	Oval pigtoe	LE	G2	Rivers	Rivers	Ap,Fl
Pleurobema riddellii	Louisiana pigtoe		G1G2	Rivers	Rivers	Ms,Sab
Pleurobema rubellum	Warrior pigtoe		GH	Rivers	Rivers	Mo
Pleurobema rubrum	Pyramid pigtoe		G2	Rivers	Rivers	Cu,Ms
Pleurobema strodeanum	Fuzzy pigtoe		G2G3	Rivers	Rivers	Ap,Mo
Pleurobema taitianum	Heavy pigtoe	LE	G1	Rivers	Rivers	Mo
Pleurobema troschelianum	Alabama clubshell	C	G1	Rivers	Rivers	Mo
Pleurobema verum	True pigtoe		GH	Rivers	Rivers	Mo
Popenaias popeii	Texas hornshell		G1	Rivers	Rivers	RG
Potamilus amphichaenus	Texas heelsplitter		G1	Rivers	Rivers	Sab
Potamilus capax	Fat pocketbook	LE	G1	Rivers	Rivers	Ms
Potamilus inflatus	Alabama heelsplitter	LT	G1	Rivers	Rivers	Ms,Mo
Ptychobranchus greenii	Triangular kidneyshell	LE	G1	Rivers	Rivers	Mo
Ptychobranchus jonesi	Southern kidneyshell		G1	Rivers	Rivers	Ap,Mo
Quadrula aurea	Golden orb		G1	Rivers	Rivers	CT
Quadrula couchiana	Rio Grande monkeyface		GH	Rivers	Rivers	RG
Quadrula cylindrica	Rabbitsfoot		G3	Rivers	Rivers	Cu,Ms
Quadrula cylindrica cylindrica	Rabbitsfoot		G3T3	Rivers	Rivers	Cu,Ms
Quadrula cylindrica strigillata	Rough rabbitsfoot	LE	G3T2T3	Rivers	Rivers	Cu,Ms
Quadrula fragosa	Winged mapleleaf	LE	G1	Rivers	Rivers	Cu,Ms
Quadrula houstonensis	Smooth pimpleback		G2	Rivers	Rivers	CT
Quadrula intermedia	Cumberland monkeyface	LE	G1	Rivers	Rivers	Cu
Quadrula petrina	Texas pimpleback		G2	Rivers	Rivers	CT
Quadrula rumphiana	Ridged mapleleaf		G3	Rivers	Rivers	Mo
Quadrula sparsa	Appalachian monkeyface	LE	G1	Rivers	Rivers	Cu
Quadrula stapes	Stirrupshell	LE	GH	Rivers	Rivers	Mo
Quadrula tuberosa	Rough rockshell		GX	Rivers	Rivers	Cu
Quincuncina burkei	Tapered pigtoe		G2G3	Rivers	Rivers	Ap
Quincuncina mitchelli	False spike		GH	Rivers	Rivers	CT,RG
Simpsonaias ambigua	Salamander mussel		G3	Rivers	Rivers	Ms
Strophitus connasaugaensis	Alabama creekshell		G3	Rivers	Rivers	Mo
Strophitus subvexus	Southern creekmussel		G3	Rivers	Rivers	Ap,Ms,Mo
Toxolasma corvunculus	Southern purple lilliput		GH	Rivers	Rivers	Mo
Toxolasma cylindrellus	Pale lilliput	LE	G1	Rivers	Rivers	Cu
Toxolasma lividus	Purple lilliput		G2	Rivers	Rivers	Cu,Ms
Toxolasma lividus lividus			G2T1	Rivers	Rivers	Cu
Toxolasma pullus	Savannah lilliput		G2	Rivers	Rivers	SA
Truncilla cognata	Mexican fawnsfoot		GH	Rivers	Rivers	RG
Truncilla macrodon	Texas fawnsfoot		G2	Rivers	Rivers	Ms
Utterbackia peggyae	Florida floater		G3	Rivers	Rivers	Ap
Utterbackia peninsularis	Pennisular floater		G3	Rivers	Rivers	Fl
Villosa amygdala	Florida rainbow		G3	Rivers	Rivers	Fl
Villosa arkansasensis	Ouachita creekshell		G2	Rivers	Rivers	Oz
Villosa choctawensis	Chocta bean		G2	Rivers	Rivers	Ap
Villosa constricta	Notched rainbow		G3	Rivers	Rivers	SA
Villosa fabalis	Rayed bean		G1G2	Rivers	Rivers	Cu,Ms
Villosa nebulosa	Alabama rainbow		G3	Rivers	Rivers	Ap,Cu Ms
Villosa ortmanni	Kentucky creekshell		G2	Rivers	Rivers	Cu

continued

Table 23.7—The rare mussels evaluated included 191 species, of which 71 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Villosa perpurpurea	Purple bean	LE	G1	Rivers	Rivers	Cu
Villosa trabalis	Cumberland bean	LE	G1	Rivers	Rivers	Cu
Villosa vaughaniana	Carolina creekshell		G2	Rivers	Rivers	SA
Villosa villosa	Downy rainbow		G3	Rivers	Rivers	Ap,Fl
Epioblasma florentina walkeri	Tan riffleshell	LE	G1T1	Streams	Streams	Cu
Fusconaia barnesiana	Tennessee pigtoe		G2G3	Streams	Streams	Cu
Lasmigona holstonia	Tennessee heelsplitter		G3	Streams	Streams	Cu,Mo
Pleurobema oviforme	Tennessee clubshell		G3	Streams	Streams	Cu
Ptychobranchus subtentum	Fluted kidneyshell		G2G3	Streams	Streams	Cu
Villosa vanuxemensis umbrans	Coosa crekshell		G4T2	Streams	Streams	Cu

ABI = Association for Biodiversity Information.
[a] Federal status: LE = listed as endangered; LT = listed as threatened; PE = proposed for listing as endangered; C = candidate for listing.
[b] See table 23.1 for definitions of ABI rankings.
[c] Primary and secondary habitat do not necessarily imply a consistent order or ranking of importance to the taxonomic group.
[d] Watersheds: Ap = Apalachicola, CT = Central Texas, Cu = Cumberland, Fl = Florida, Mo = Mobile, Ms = Mississippi, NA = North Atlantic, Oz = Ozark, RG = Rio Grande, SA = South Atlantic, Sab = Sabine.
Source: NatureServe 2001a.

Other important areas for mussels include the Mississippi watershed; the Apalachicola, Ochlockonee, and Suwannee River watersheds; and the South Atlantic Rivers (fig. 23.12).

Threats to mussels—The threats to viability of freshwater mussels are many and compounding in their impacts. Parmalee and Bogan (1998) stated, "The greatest overall detrimental impact on mussel populations probably can be attributed, directly or indirectly, to dam construction—especially those built in the 1930s, 1940s and 1950s." Numerous recovery plans published by the U.S. Department of the Interior, Fish and Wildlife Service (Ahlstedt 1983, U.S. Department of the Interior, Fish and Wildlife Service 2000) also identify dams as the most important factor in the decline of mussels.

The most direct effect of dams on mussels is the immediate loss of flowing water upstream of the dam site. Once their habitat is inundated by a reservoir, the mussels living there are unable to move to suitable riverine habitat. In addition, reproduction will not occur if the fish

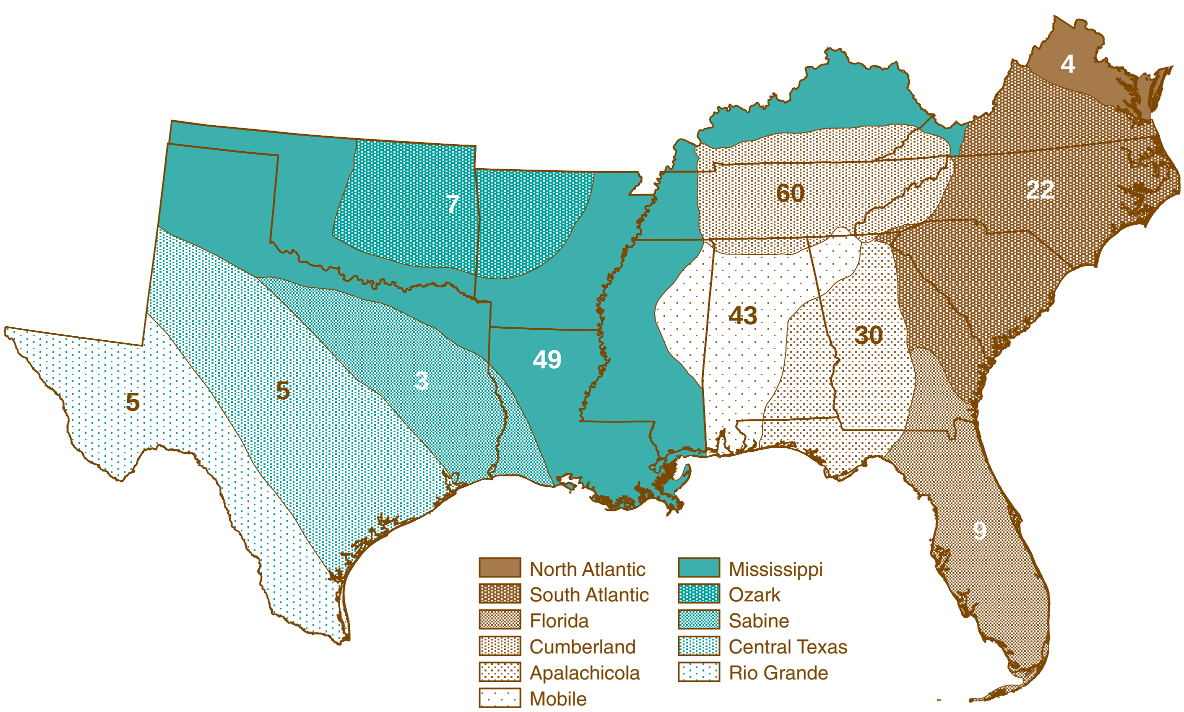


Figure 23.12—Rare mussels occur in all 11 of the aquatic fauna provinces described by Parmalee and Bogan (1998). The Cumberland Province, including the Tennessee and Cumberland River systems, supports the greatest number of rare mussels.

host is similarly adapted to riverine environments. Bogan (1993) described mussels stranded in reservoirs as "functionally extinct when the host fish is no longer present." Although, historically, subpopulations of the same species may have been separated by several miles in a river, their dispersal schemes (glochidia attached to more mobile fish), allowed the flow of genes between the cohorts. Currently, subpopulations that are separated by a few miles are often genetically isolated by dams.

The plight of these mussels is aggravated by the accumulation of sediment that would normally move through the system. Because flow is often restricted in reservoirs, sediment can settle and accumulate.

To adequately consider the habitat needs of freshwater mussels, it is important to include the needs of their fish hosts. Freshwater mussels spend some time as a parasitic larva (glochidia) attached to the gills or fins of various fish species. The fish hosts for many of the rare mussels are unknown (Ahlstedt 1983); however, this aspect of freshwater mussel ecology is being actively researched (Neves and others 1997). Turbid water may inhibit the sight-feeding fish hosts, which must find the glochidia (NatureServe 2001). Therefore, for riverine fauna to remain viable, measures to reduce the amount of sediment that reaches the bottom habitats in streams are necessary.

Transportation and accumulation of sediment occur in all river habitats. The principal sources of sediment to rivers and their relative level of significance are discussed in detail in chapter 19.

Sediment can clog gills of mussels, reducing feeding efficiency and interfering with mussel and host fish interactions. Heavy sediment loads can also potentially smother individual mussels. Sediments result from agricultural, silvicultural, mining, urban development, road construction, and other activities on the land (Neves and others 1997). According to Neves and others (1997), agriculture is the most widely reported source of pollutants. Streamside buffer strips can significantly reduce soil and nutrient concentrations in surface runoff.

In addition to this sediment threat in the Southeastern United States, excessive nutrients and pesticides from intensive agriculture or silviculture could affect mussels. Although mussels can close their valves to avoid short-term exposure to pollutants, the effects of chronic exposures are mostly unknown. Neves and others (1997) emphasized the need to set water-quality criteria by using early life-history stages for toxicity testing. Other pollutants potentially affecting mussels include petroleum spills, industrial discharges, and highway salts (Abell and others 2000, Hart and Fuller 1974, Neves and others 1997). Coal mining can produce sediment runoff and alter water chemistry with acid drainage and heavy metals (Neves and others 1997).

On many large and medium-sized rivers, continual dredging is often necessary to maintain an appropriate channel for barge traffic (Abell and others 2000). Dredging can make the river substrate unstable and unsuitable for mussels (Hart and Fuller 1974). On smaller streams, relocating or straightening channels can reduce habitat diversity and stability of the bottom substrates. Dredging can also remove mussels from their beds. Commercial sand and gravel dredging operations can have similar effects (Neves and others 1997).

Water withdrawals can sometimes compound these threats, especially in small streams. Because they have less volume of water, small streams often are exposed to higher concentrations of pollutants than larger streams. Water withdrawals for rural and urban uses may also reduce base flows of small streams, shrinking available mussel habitat (Abell and others 2000).

Two exotic mussel species, Asian clams and zebra mussels, directly compete with native mussels for food and space, especially in reservoirs and large rivers (Bogan 1993). Zebra mussels may attach to native mussels in large enough numbers to weaken or kill the natives. Zebra mussels (living and dead) may also accumulate in such densities that they significantly alter the physical characteristics of the substrate as well as the water quality.

Future for mussels—The ways in which mussel habitats are affected by human activities vary little between watersheds; consequently, this Assessment focuses on stream size without emphasis on drainage unit.

The long-term status of many river mussels is undetermined at present. Neves and others (1997) stated, "Because mussels are thought to be the longest lived freshwater invertebrates, with a longevity of more than 100 years for some species, population declines may continue for decades. Thus, the extirpation of species is a prolonged event, lagging decades behind the directly responsible factors of attrition of the fauna."

The system of dams along the 650 miles of the Tennessee River from Knoxville, TN, to Paducah, KY, was designed so that even at the lowest operating pool level, the water behind one dam backed up to the next (Ungate 1990), essentially eliminating any free-flowing water. Flow of the Cumberland and Mobile Rivers is similarly restricted (U.S. Department of the Interior, Fish and Wildlife Service 2000). However, there are still some relatively riverine sections of these systems. The methods of operating the dams can improve downstream water and habitat quality, providing additional habitat (Yeager 1993).

In free-flowing segments of rivers, mussel communities may be wholly or partially intact, but the populations probably have become genetically isolated from other populations of the same species. Chance events probably also take a toll on these isolated populations, which have no natural means of being augmented and little habitat suitable for expansion. Many rare mussel species that depend on river habitats may not be able to sustain themselves. However, recent advances in technology have stimulated proposals for augmenting or reintroducing captively propagated individuals (U.S. Federal Register 2001a) in some of these large river habitats.

Rare mussels that are typically found in stream habitats are subject to the same environmental impacts as mussels in the rivers, but they could be affected more severely by changes in water quality and quantity. For example, streams are more often affected by road and railroad crossings, and roads that parallel their courses. The likelihood for accidental spills from trucks or trains is high. Chemical spills pose a serious threat to many isolated mussel populations. Fish hosts and mussel glochidia may be more susceptible to acute toxicity than adult mussels (Rand and Petrocelli 1985), but adult mussels may be more susceptible to chronic exposures, especially those from materials that accumulate in their bodies (Fridell 1996).

Urban and agricultural pesticides enter river systems either directly as they are sprayed onto the body of water or indirectly as residues attached to soil particles that wash into the stream following a storm (U.S. Department of Agriculture, Forest Service 1989). Some of these pesticides, such as 2,4-D, are known to be extremely toxic to fish and many invertebrates (Johnson and Finley 1980, Mayer and Ellersieck 1986). Yet, the potential toxicity of these chemicals to the majority of mussel or fish (host) species is unknown. However, recent advances in technology that improve captive production of mussels may allow for toxicity testing to more accurately set water-quality standards (Neves and others 1997). The effects of agricultural chemicals on the reproductive success of mussels also need to be researched. Minuscule amounts of pesticide may mimic natural hormones (Neves and others 1997). This threat is difficult to recognize because adult mussels may remain in the river for years without reproducing.

Mining, chemical, manufacturing, and wood-product wastes entering rivers from point sources are subject to environmental reviews for permitting and monitoring (Fridell 1996). However, water-quality standards used in this permitting usually are not based on toxicity testing of rare species. Mussels and their fish hosts may be more sensitive than the organisms tested to establish the standards. Therefore, permitted activities may indeed affect the rare mussels and fish. Threats to water quality can also arise when retention ponds are overwhelmed by a storm. The chemical wastes associated with these activities could have direct and immediate effects on the fish and mussels, and some of these toxicants may persist for months or even years. As suggested above, the ability to captively produce enough individuals of the more sensitive aquatic species to use in setting water-quality standards could improve this situation.

Water withdrawals for domestic, agricultural, or industrial uses diminish the wetted stream bottom and could reduce available habitat for mussels and their host fishes. Although typically, there are limits on individual withdrawals and minimum flow requirements, demands for water are increasing in the South.

Fish—Like most of the other aquatic animal groups discussed here, the Southeastern United States is well known by biologists for its high diversity of freshwater fish (Warren and others 1997, 2000). Nearly half of the North American fish fauna is found in this region (Warren and others2000). Etnier (1994) noted that only two southern fish (hairlip sucker, *Moxostoma lacerum*, and whiteline topminnow, *Fundulus albolineatus*) are known to be extinct. Two others (Scioto madtom, *Noturus trautmani*, and Maryland darter, *Etheostoma sellare*) are also believed to be probably extinct. The Southeast also contains a high proportion of fish currently considered jeopardized. Warren and others (2000) listed 28 percent of the 662 native freshwater or diadromous southern fish as jeopardized. They noted this was a 75-percent increase in the proportion of jeopardized fish since 1989, and 125 percent since 1979. Although there are still gaps in knowledge, freshwater fish are better known than many other aquatic animals discussed in this Assessment. Etnier (1994) pointed out that, even though we have relatively more data on southeastern freshwater fish than some other groups, our knowledge is still inadequate to accurately assess the status of many, possibly declining fish. He recommended more long-term monitoring efforts.

The 165 rare fish assessed (table 23.8) belong to 14 families (fig. 23.13). Rivers, streams, and ground water habitats are the major habitats where they occur most often (fig. 23.14).

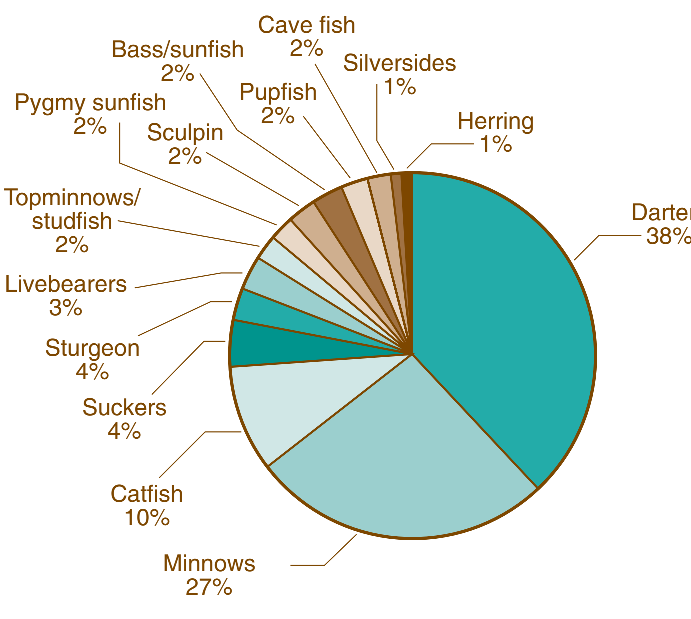


Figure 23.13—The 165 rare fish species are divided among 14 families. The darter, minnow, and catfish families contain 75 percent of the species considered in this Assessment.

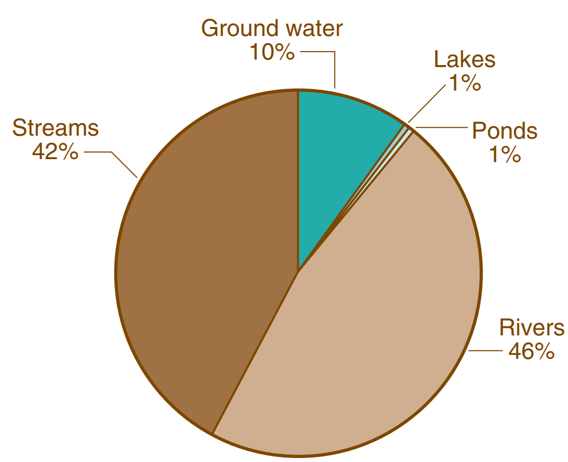


Figure 23.14—The 165 rare fish evaluated use all 5 aquatic habitats. Lakes and ponds combined support only about 2 percent of the species.

Table 23.8—The rare fish evaluated included 165 species, of which 45 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Acipenser brevirostrum	Shortnose sturgeon	LE	G3	Rivers	Rivers	NA,SA,Fl
Acipenser fulvescens	Lake sturgeon		G3	Rivers	Rivers	Mo,Ms,Cu
Acipenser oxyrinchus	Atlantic sturgeon	LT, C	G3	Rivers	Rivers	NA,SA,Fl
Acipenser oxyrinchus desotoi	Gulf sturgeon	LT	G3T2	Rivers	Rivers	Fl,Ap,Mo,Ms
Alosa alabamae	Alabama shad	C	G3	Rivers	Rivers	Fl,Ap,Mo, Ms, Cu,Oz
Ambloplites cavifrons	Roanoke bass		G3	Streams	Streams	SA
Amblyopsis rosae	Ozark cavefish	LT	G2	Ground water	Ground water	Oz
Amblyopsis spelaea	Northern cavefish		G3	Ground water	Ground water	Ms
Ameiurus serracanthus	Spotted bullhead		G3	Streams	Streams	Fl,Ap
Ammocrypta clara	Western sand darter		G3	Rivers	Rivers	Ms,Cu,Oz,Sab
Ammocrypta pellucida	Eastern sand darter		G3	Rivers	Rivers	Cu,Ms
Campostoma ornatum	Mexican stoneroller		G3	Rivers	Streams	RG
Cottus paulus	Pygmy sculpin	LT	G1	Ground water	Ground water	Mo
Cottus sp. 1	Bluestone sculpin		G2	Streams	Streams	Ms
Cottus sp. 4	Clinch sculpin		G1G2	Streams	Streams	Cu
Cottus sp. 5	Holston sculpin		G2	Streams	Streams	Cu
Crystallaria asprella	Crystal darter		G3	Rivers	Rivers	Ms
Cyprinella caerulea	Blue shiner	LT	G2	Rivers	Rivers	Mo
Cyprinella callisema	Ocmulgee shiner		G3	Rivers	Rivers	SA
Cyprinella callitaenia	Bluestripe shiner		G2	Rivers	Rivers	Ap
Cyprinella lepida	Plateau shiner		G1G2	Streams	Streams	CT
Cyprinella monacha	Spotfin chub	LT	G2	Rivers	Rivers	Cu
Cyprinella proserpina	Proserpine shiner		G3	Rivers	Rivers	RG
Cyprinella xaenura	Altamaha shiner		G1G2	Rivers	Rivers	SA
Cyprinodon bovinus	Leon Springs pupfish	LE	G1	Ground water	Ground water	RG
Cyprinodon elegans	Comanche Springs pupfish	LE	G1	Ground water	Ground water	RG
Cyprinodon pecosensis	Pecos pupfish	C	G1	Streams	Streams	RG
Dionda argentosa	Manantial roundnose minnow		G2	Streams	Rivers	RG
Dionda diaboli	Devil's river minnow	C	G1	Streams	Rivers	RG
Dionda serena	Nueces roundnose minnow		G2	Streams	Rivers	CT
Elassoma alabamae	Spring pygmy sunfish		G1	Streams	Streams	Cu
Elassoma boehlkei	Carolina pygmy sunfish		G2	Streams	Streams	SA
Elassoma okatie	Bluebarred pygmy sunfish		G2G3	Streams	Streams	SA
Elassoma sp. 3	Jewel pygmy sunfish		G1	Streams	Streams	SA
Erimystax cahni	Slender chub	LT	G1G2	Rivers	Rivers	Cu
Etheostoma acuticeps	Sharphead darter		G2G3	Rivers	Rivers	Cu
Etheostoma aquali	Coppercheek darter		G2	Rivers	Rivers	Cu
Etheostoma bellator	Warrior darter		G2	Rivers	Rivers	Mo
Etheostoma boschungi	Slackwater darter	LT	G1	Streams	Streams	Cu
Etheostoma brevirostrum	Holiday darter		G2	Rivers	Rivers	Mo
Etheostoma chermocki	Vermilion darter	PE	G1	Streams	Streams	Mo
Etheostoma chienense	Relict darter	LE	G1	Streams	Streams	Ms
Etheostoma chuckwachatte	Lipstick darter		G2G3	Streams	Rivers	Mo
Etheostoma cinereum	Ashy darter		G2	Streams	Streams	Cu
Etheostoma collis	Carolina darter		G3	Streams	Streams	SA
Etheostoma corona	Crown darter		G1G2	Streams	Streams	Cu
Etheostoma cragini	Arkansas darter	C	G3	Streams	Streams	Oz
Etheostoma denoncourti	Golden darter		G2	Streams	Rivers	Cu
Etheostoma ditrema	Coldwater darter		G1G2	Ground water	Streams	Mo
Etheostoma douglasi	Tuskaloosa darter		G2	Streams	Rivers	Mo
Etheostoma etowahae	Etowah darter	LE	G1	Streams	Rivers	Mo
Etheostoma fonticola	Fountain darter	LE	G1	Ground water	Streams	CT
Etheostoma forbesi	Barrens darter		G1G2	Streams	Streams	Cu
Etheostoma grahami	Rio Grande darter		G3	Rivers	Rivers	RG
Etheostoma maculatum	Spotted darter		G2	Rivers	Rivers	Ms
Etheostoma mariae	Pinewoods darter		G3	Streams	Streams	SA
Etheostoma microlepidum	Smallscale darter		G2G3	Rivers	Rivers	Cu
Etheostoma moorei	Yellowcheek darter		G1	Streams	Streams	Oz
Etheostoma neopterum	Lollipop darter		G1G2	Streams	Streams	Cu
Etheostoma nuchale	Watercress darter	LE	G1	Ground water	Streams	Mo
Etheostoma okaloosae	Okaloosa darter	LE	G1	Streams	Streams	Ap

continued

AQUATIC

Table 23.8—The rare fish evaluated included 165 species, of which 45 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Etheostoma olivaceum	Sooty darter		G3	Streams	Streams	Cu
Etheostoma osburni	Candy darter		G3	Streams	Streams	Ms
Etheostoma pallididorsum	Paleback darter		G2	Streams	Streams	Ms
Etheostoma percnurum	Duskytail darter	LE	G1	Rivers	Rivers	Cu
Etheostoma phytophilum	Rush darter		G1	Streams	Streams	Mo
Etheostoma pseudovulatum	Egg-mimic darter		G1	Streams	Streams	Cu
Etheostoma pyrrhogaster	Firebelly darter		G2	Streams	Streams	Ms
Etheostoma raneyi	Yazoo darter		G2	Streams	Streams	Ms
Etheostoma rubrum	Bayou darter	LT	G1	Streams	Streams	Ms
Etheostoma scotti	Cherokee darter	LT	G2	Streams	Streams	Mo
Etheostoma sp. d	Bluemask (jewel) darter	LE	G1	Streams	Rivers	Cu
Etheostoma striatulum	Striated darter		G1	Streams	Streams	Cu
Etheostoma susanae	Cumberland johnny darter	C	G2	Streams	Streams	Cu
Etheostoma tecumsehi	Shawnee darter		G1	Streams	Streams	Ms
Etheostoma tippecanoe	Tippecanoe darter		G3	Rivers	Rivers	Cu,Ms
Etheostoma trisella	Trispot darter		G1	Rivers	Streams	Mo
Etheostoma tuscumbia	Tuscumbia darter		G2	Ground water	Ground water	Cu
Etheostoma vulneratum	Wounded darter		G3	Rivers	Rivers	Cu
Etheostoma wapiti	Boulder darter	LE	G1	Rivers	Rivers	Cu
Fundulus albolineatus	Whiteline topminnow		GX	Ground water	Ground water	Cu
Fundulus bifax	Stippled studfish		G2G3	Streams	Rivers	Mo
Fundulus euryzonus	Broadstripe topminnow		G2	Rivers	Rivers	Ms
Fundulus julisia	Barrens topminnow		G1	Ground water	Ground water	Cu
Gambusia amistadensis	Amistad gambusia		GX	Ground water	Streams	RG
Gambusia gaigei	Big Bend gambusia	LE	G1	Ground water	Ponds	RG
Gambusia georgei	San Marcos gambusia	LE	GX	Rivers	Ground water	RG
Gambusia heterochir	Clear Creek gambusia	LE	G1	Streams	Streams	CT
Gambusia nobilis	Pecos gambusia	LE	G2	Ground water	Streams	RG
Gila pandora	Rio Grande chub		G3	Streams	Streams	RG
Hemitremia flammea	Flame chub		G3	Ground water	Ground water	Mo,Cu
Hybognathus amarus	Rio Grande silvery minnow	LE	G1G2	Streams	Streams	RG
Hybopsis lineapunctata	Lined chub		G3	Streams	Streams	Mo
Ictalurus lupus	Headwater catfish		G3	Streams	Rivers	CT
Lythrurus matutinus	Pinewoods shiner		G2G3	Streams	Streams	SA
Lythrurus snelsoni	Ouachita shiner		G2	Streams	Streams	Ms
Macrhybopsis gelida	Sturgeon chub	C	G2	Rivers	Rivers	Ms
Macrhybopsis meeki	Sicklefin chub	C	G3	Rivers	Rivers	Ms
Macrhybopsis sp. 2	Florida chub		G3	Rivers	Rivers	Ap
Menidia extensa	Waccamaw silverside	LT	G1	Lakes	Lakes	SA
Micropterus cataractae	Shoal bass		G3	Rivers	Streams	Ap
Micropterus notius	Suwannee bass		G2G3	Rivers	Streams	Fl
Micropterus treculi	Guadalupe bass		G3	Rivers	Streams	CT
Moxostoma lacerum	Harelip sucker		GX	Rivers	Rivers	Cu,Ms
Moxostoma robustum	Robust redhorse		G1	Rivers	Rivers	SA
Moxostoma sp. 1	Apalachicola redhorse		G3	Rivers	Rivers	Ap
Moxostoma valenciennesi	Greater redhorse		G3	Rivers	Rivers	Ms
Notropis albizonatus	Palezone shiner	LE	G2	Rivers	Streams	Cu
Notropis ariommus	Popeye shiner		G3	Streams	Rivers	Cu,Ms
Notropis cahabae	Cahaba shiner	LE	G2	Rivers	Rivers	Mo
Notropis chihuahua	Chihuahua shiner		G3	Streams	Ground water	RG
Notropis girardi	Arkansas River shiner	LT	G2	Rivers	Rivers	Oz
Notropis hypsilepis	Highscale shiner		G3	Streams	Streams	Ap
Notropis jemezanus	Rio Grande shiner		G3	Rivers	Rivers	RG
Notropis mekistocholas	Cape Fear shiner	LE	G1	Rivers	Streams	SA
Notropis melanostomus	Blackmouth shiner		G2	Ponds	Rivers	Ap,Ms
Notropis ortenburgeri	Kiamichi shiner		G3	Streams	Streams	Oz,Ms
Notropis oxyrhynchus	Sharpnose shiner		G3	Rivers	Rivers	CT
Notropis ozarcanus	Ozark shiner		G3	Rivers	Streams	Ms,Oz
Notropis perpallidus	Peppered shiner		G3	Rivers	Rivers	Ms
Notropis rupestris	Bedrock shiner		G2	Streams	Streams	Cu
Notropis semperasper	Roughhead shiner		G2G3	Rivers	Rivers	SA
Notropis simus	Bluntnose shiner	LT	G2	Rivers	Rivers	RG

continued

Table 23.8—The rare fish evaluated included 165 species, of which 45 are federally listed as threatened or endangered (continued)

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]	Watersheds[d]
Notropis suttkusi	Rocky shiner		G3	Rivers	Rivers	Ms
Notropis uranoscopus	Skygazer shiner		G2	Rivers	Rivers	Mo
Noturus baileyi	Smoky madtom	LE	G1	Rivers	Rivers	Cu
Noturus flavipinnis	Yellowfin madtom	LT	G1	Rivers	Rivers	Cu
Noturus furiosus	Carolina madtom		G3	Streams	Streams	SA
Noturus gilberti	Orangefin madtom		G2	Rivers	Streams	SA
Noturus lachneri	Ouachita madtom		G2	Streams	Streams	Ms
Noturus munitus	Frecklebelly madtom		G3	Rivers	Rivers	Mo
Noturus placidus	Neosho madtom	LT	G2	Rivers	Rivers	Oz
Noturus sp. 2	Broadtail madtom		G2	Rivers	Rivers	SA
Noturus sp. 4	Chucky madtom		G1	Streams	Streams	Cu
Noturus stanauli	Pygmy madtom	LE	G1	Rivers	Rivers	Cu
Noturus stigmosus	Northern madtom		G3	Rivers	Rivers	Ms
Noturus taylori	Caddo madtom		G1	Rivers	Rivers	Ms
Percina antesella	Amber darter	LE	G2	Rivers	Rivers	Mo
Percina aurolineata	Goldline darter	LT	G2	Rivers	Rivers	Mo
Percina aurora	Pearl darter	C	G1	Rivers	Rivers	Ms
Percina austroperca	Southern logperch		G3	Rivers	Rivers	Ap
Percina brevicauda	Coal darter		G2	Rivers	Rivers	Mo
Percina burtoni	Blotchside darter		G2	Rivers	Rivers	Cu
Percina jenkinsi	Conasauga logperch	LE	G1	Rivers	Rivers	Mo
Percina lenticula	Freckled darter		G2	Rivers	Rivers	Mo,Ms
Percina macrocephala	Longhead darter		G3	Rivers	Rivers	Cu,Ms
Percina nasuta	Longnose darter		G3	Streams	Rivers	Ms,Oz
Percina pantherina	Leopard darter	LT	G1	Streams	Streams	Ms
Percina rex	Roanoke logperch	LE	G2	Rivers	Rivers	SA
Percina squamata	Olive darter		G2	Rivers	Rivers	Cu
Percina tanasi	Snail darter	LT	G2	Rivers	Rivers	Cu
Percina uranidea	Stargazing darter		G3	Rivers	Rivers	Ms,Oz
Phoxinus cumberlandensis	Blackside dace	LT	G2	Streams	Streams	Cu
Phoxinus tennesseensis	Tennessee dace		G2G3	Streams	Streams	Cu
Pteronotropis euryzonus	Broadstripe shiner		G3	Streams	Streams	Ap
Pteronotropis hubbsi	Bluehead shiner		G3	Streams	Ponds	Ap
Satan eurystomus	Widemouth blindcat		G1	Ground water	Ground water	CT
Scaphirhynchus albus	Pallid sturgeon	LE	G1G2	Rivers	Rivers	Ms
Scaphirhynchus suttkusi	Alabama sturgeon	C	G1	Rivers	Rivers	Mo
Scartomyzon austrinus	West Mexican redhorse		G3	Streams	Rivers	RG
Semotilus lumbee	Sandhills chub		G3	Streams	Streams	SA
Speoplatyrhinus poulsoni	Alabama cavefish	LE	G1	Ground water	Ground water	Cu
Thoburnia atripinnis	Blackfin sucker		G2	Streams	Streams	Ms
Thoburnia hamiltoni	Rustyside sucker		G2	Streams	Streams	SA
Trogloglanis pattersoni	Toothless blindcat		G1	Ground water	Ground water	CT

ABI = Association for Biodiversity Information.

[a] Federal status: LE = listed as endangered; LT = listed as threatened; PE = proposed for listing as endangered; C = candidate for listing.

[b] See table 23.1 for definitions of ABI rankings.

[c] Primary and secondary habitat do not necessarily imply a constistent order or ranking of importance to the taxonomic group.

[d] Watersheds: Ap = Apalachicola, CT = Central Texas, Cu = Cumberland, Fl = Florida, Mo = Mobile, Ms = Mississippi, NA = North Atlantic, Oz = Ozark, RG = Rio Grande, SA = South Atlantic, Sab = Sabine.

Source: NatureServe 2000b.

Etnier and Starnes (1991) noted that darters and madtom catfish are more likely to be jeopardized than would be expected, based on their representation in the fauna. These groups of fish have highly specialized reproductive requirements, which probably also contribute to their sensitivity. Angermeier (1995) also noted that ecological specialists are more extinction-prone than are generalists. These animals normally have life-history requirements that include the use of crevices beneath or between rocks and a clean stream bottom. Darters (63 of the fishes discussed here) occupy a wide variety of habitats ranging from small springs to fast-flowing riffles in large rivers to backwater areas in swamps (Burr and Warren 1986. Etnier and Starnes 1993, Jenkins and Burkhead 1993, Pflieger 1975, Smith-Vaniz 1968). Many darters are considered clean-water species (Etnier and Starnes 1993) that are sensitive to sedimentation. Most are sight feeders and many species care for their eggs and young. Like many other groups previously discussed, some darter species are restricted to relatively small geographical areas, often a single watershed (Etnier and Starnes 1993, Jenkins and Burkhead 1993, Warren and others 2000).

Minnows (46 species discussed here) are generally sight feeders, taking microorganisms and organic matter from the water column. Reproductive activities range from spawning in association with nests built by a larger minnow, placing eggs in crevices in rocks or logs, and attaching eggs to submerged plants or gravel (Etnier and Starnes 1993). Although some minnows protect their nests, many eggs are scattered or attached and left alone. Some rare minnows are geographically restricted to small watersheds.

The 16 rare catfish included in this Assessment are predominately madtoms. Spawning occurs beneath rocks or other objects on or near the substrate. Eggs and young are guarded by the males and are well protected (Burr and Stoeckel 1999, Etnier and Starnes 1993). Most catfish are nocturnal feeders, relying on their highly sensitive barbels to detect aquatic insects. They also apparently rely heavily on “taste” or “smell” to find mates or make other observations about what goes on in their waters (Todd 1973). The rare madtoms, headwater catfish, and spotted bullhead are found in small to medium-sized streams; many species have highly localized populations. The two cave catfish included here are found in groundwater systems restricted to Edward’s Aquifer in Texas. All of these catfish are endemic with highly localized populations (Burr and Stoeckel 1999).

Seven suckers are included in this Assessment. These fish use small to large streams. They feed on invertebrates that they stir up by nudging their heads into gravel and cobble streambeds (Etnier and Starnes 1993). Therefore, a loose substrate is essential for their foraging. Spawning occurs in similar areas; eggs are buried beneath the gravel and cobbles, which are disturbed by the tail movements of the fish. Some species build rough nests, but no parental protection is provided for the eggs or fry (Etnier and Starnes 1993).

The sturgeons included in this Assessment (six species) are all relatively long-lived fish that can reach a large size. They are prized for their flesh and eggs (Etnier and Starnes 1993), although the Federal protection status of most of the species listed in this Assessment does not allow for legal harvest. Sturgeons are bottom feeders, using their barbels to find food organisms, which include crayfish, mussels, snails, and insects (Jenkins and Burkhead 1993). Spawning migrations may cover more than 100 miles; individual fish do not spawn every year, and sexual maturity may not be reached until the fish is 14 to 30 years old (Jenkins and Burkhead 1993). Spawning occurs in shallow water, and no parental care is provided to the eggs or fry (Etnier and Starnes 1993). Several of these characteristics, including late maturity and infrequency of spawning, render all the sturgeon species exceptionally vulnerable.

The five species of live-bearers included in this Assessment are restricted to warmwater springs and spring runs in Texas (NatureServe 2000). Two of these species are believed to be nearing extinction, if they aren’t already extinct (Williams and others 1989). These fish are all midwater feeders, taking insects, amphipods, filamentous algae, and young fish (Lee and others 1980). Spawning can take place year round. In comparison with most other fishes, which hatch from eggs, possess a large yolk sac, and are relatively helpless for a while, live-bearer young are born fully developed (Lee and others 1980).

Four rare species of topminnows and studfish are included in this Assessment. All of these species prefer small streams, springs, or the margins of rivers and are closely associated with cover (Etnier and Starnes 1993). They feed near the surface on invertebrates. All spawn over a substrate of rock or attach their eggs among vegetation; no parental care to the eggs or fry is provided (Etnier and Starnes 1993).

The four pygmy sunfish included in the Assessment prefer springs, spring runs, or blackwater swamps, where they feed on crustaceans (Etnier and Starnes 1993, NatureServe 2000). The life spans of most pygmy sunfish species are probably not much longer than 1 year (Etnier and Starnes 1993). The distributions of several species are geographically isolated, and some are found in only a few localities (Rohde and Arndt 1987).

The four sculpin evaluated in this Assessment are restricted to small, coldwater streams or springs. Three are found in headwaters of the Tennessee River drainage in Virginia, and one is found in a single spring in the Mobile River basin in Alabama (Jenkins and Burkhead 1993, Mettee and others 1996). All four are narrow endemics occupying very small geographic areas. Sculpins are predators. They feed on aquatic insect larvae, crayfish, and fish, usually ambushing their prey at night from beneath the cover of rocks (Jenkins and Burkhead 1993). Spawning takes place in cavities under rocks excavated by males (Jenkins and Burkhead 1993). The males care for the eggs until they hatch (Etnier and Starnes 1993).

The bass and sunfish evaluated in this Assessment include three black bass and one rockbass. These all prefer small to medium-sized streams (Lee and others 1980), where they feed on crayfish, other invertebrates, and small fish (Jenkins and Burkhead 1993). Males construct nests and provide protection for their eggs and fry (Lee and others 1980). All of these species are considered sport fish.

Two of the three pupfish evaluated are restricted to springs; the others occur in streams (NatureServe 2000). All three are endemic to Texas. These small fish may exist in loose gravel when no surface water is present. They spawn over gravel; the male defends a territory, but does not provide any protection for the eggs. Food includes microscopic benthic organisms (NatureServe 2000).

The three cavefish are all narrow endemics restricted to cave systems in the Mississippi, Cumberland, and Ozark watersheds. They feed on copepods, crayfish, salamanders, and their young (Pflieger 1975). Spawning activity has not been documented; however, Etnier and Starnes (1993) speculate that they may be mouth brooders.

The Waccamaw silverside is the only silverside included in this Assessment. This species probably only lives for about 1 year (Shute 1997). Silversides are upper-water residents that school in large numbers. They feed on small, planktonic invertebrates and are believed to spawn in open water, providing no protection for the eggs or young (NatureServe 2000). This fish is especially vulnerable because of its short lifespan, and because it is a narrow endemic, being restricted to a single lake in North Carolina.

The distribution of rare fish across the South (fig. 23.15) is remarkably similar to the rare mussel distribution. In fact, the three watersheds (Cumberland, Mississippi, and Mobile) with the highest number of rare mussels and rare fish are the same. The South Atlantic and Apalachicola are also high for both species groups. The Rio Grande is a significant watershed for rare fish.

Threats to fish—Threats to fish are many, cumulative, and interactive. The most frequent explanation for declines in southern fish is habitat alteration, which has affected all habitat types (Etnier 1997, Warren and others 1997, Williams and others 1989). Physical habitat alteration resulting from impoundment, channelization, dredging, sedimentation, ditch cleaning, and other changes that result from land treatments could affect darters, minnows, catfish, bass, pygmy sunfish, and sculpins, for example (Warren and others 2000).

Many of the fish (excluding the wider-ranging minnows, herrings, suckers, and sturgeons) considered in this Assessment have apparently always been narrow endemics (Warren and others 2000). Others currently exist in fragmented populations because of habitat alterations. Consequently, the small, isolated populations that remain are subject to extinction from a few or even a single natural chance or accidental event.

Reservoirs have flooded much of the preferred habitats for fish in at least six of the family groups discussed here. For example, the Amistad gambusia went extinct when Amistad Reservoir flooded its only known location (NatureServe 2000). However, in spite of the many reservoirs found throughout the South, many populations of sensitive fishes still exist (Etnier 1994). Populations remaining are often widely separated and therefore much more vulnerable to single catastrophic events (Angermeier 1995, Warren and others 2000). Dams have also blocked migration routes for suckers, herrings, and sturgeons.

Chronic buildup of sediments and prolonged periods of turbidity can adversely affect feeding, spawning, and cover availability. Sight feeders, such as the rare Conasauga logperch, forage by flipping rocks over with their snouts and feeding on the aquatic insects found on the bottom of the rock they have just flipped. Rocks imbedded in silt are not easily moved, and they

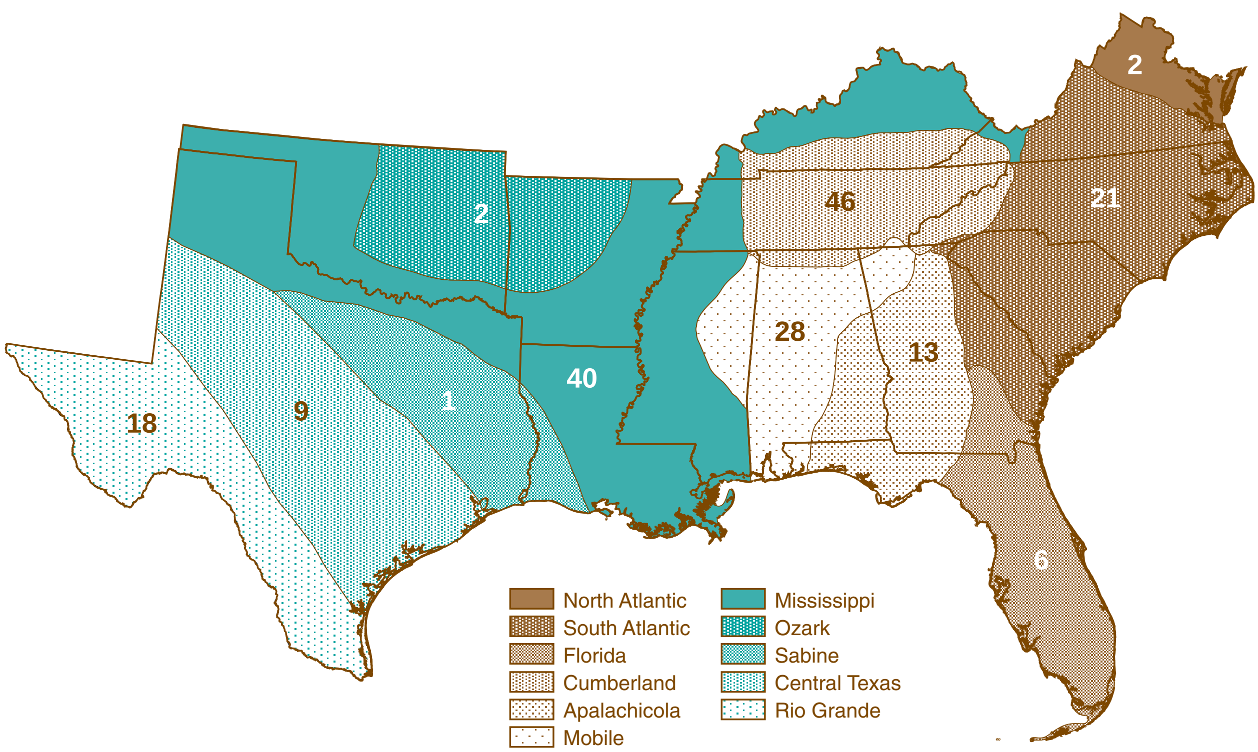


Figure 23.15—Rare fish occur in all 11 of the aquatic fauna provinces described by Parmalee and Bogan (1998). The Cumberland Province, including the Tennessee and Cumberland River systems, supports the greatest number of rare fish.

support fewer aquatic invertebrates for darters and other fishes that feed similarly (Etnier and Starnes 1993). Since most darters and madtoms and some of the other fishes included here (suckers and some minnows) deposit their eggs on or near the substrate, sediment buildup impacts their spawning success. Many darters also seek cover from predators in the spaces between rocks. Sediment fills these spaces and eliminates the essential cover.

In addition, many other sensitive fish discussed in this Assessment are especially vulnerable to impacts of human activities simply because of their life histories. For example, some sturgeons do not become sexually mature until they are 15 to 30 years old (Etnier and Starnes 1993), and then they only reproduce periodically, exposing themselves to years of habitat alterations and pollution, and potential harvest by humans before they are even able to produce offspring. Conversely, some other fishes are extremely short-lived. For example, the pygmy sunfish and the Waccamaw silverside seldom live for more than 1 year (Jenkins and Burkhead 1993, Rohde and Arndt 1987, Shute 1997). If some factor results in poor reproductive success during a single spawning season, the entire population could be lost.

Pollution and sediment threats from mining, industrial, and agricultural activities; accidental spills; and urban expansion have already, or potentially could, impact most of the fish family groups or their food resources (Warren and others 2000). Sediment reduces available food organisms and may inhibit maturation of eggs, especially for crevice-spawning minnows or species with bottom-dwelling larvae and young, like madtoms, darters, and some minnows. For other animal groups, developing water-quality standards based on toxicity testing of more sensitive fish species could improve this situation.

Water withdrawal resulting in aquifer drawdown and contamination of ground water is potentially a serious threat to spring and cave-adapted species (Elliott 2000, Etnier 1997, Etnier and Starnes 1991, Hubbs 1995, Warren and others 2000). These sensitive fish include some of the topminnows, pupfish, live-bearers, and cavefish. Animals living in these habitats are more vulnerable to pollution and sedimentation, because of their inability to adapt to water quality and habitat changes in their relatively stable environments.

While not as obvious in the Southeast as in the Western United States, introductions of nonnative fishes can result from stocking, bait-bucket releases, and interbasin connections (Nico and Fuller 1999, Sheldon 1988). Competition from introduced species threatens some topminnows, pupfish, bass, and live-bearers; hybridization is a potential threat to some darters, minnows, topminnows, pupfish, and bass. Predation from introduced species threatens darters, suckers, madtom catfishes, and silversides (NatureServe 2000). The San Marcos gambusia, a live-bearer, apparently was forced into extinction from a combination of events including competition and hybridization (NatureServe 2000).

Overharvesting and collecting for bait or aquarium trade are affecting or have affected suckers, bass, pygmy sunfish, sturgeon, topminnows, pupfish, and cavefish (NatureServe 2000).

Future for fish—Many of the rare darters included here are narrowly endemic species subject to catastrophic losses from relatively minor accidents or chance events. A single spill of toxic chemicals could drastically reduce or eliminate a population. Therefore, protecting important stream-bottom habitats and water quality by preventing runoff and spills is important to ensure their continued existence. Because these populations are geographically isolated and reinvasions are not likely because of habitat barriers, augmentation or reintroduction may be necessary to ensure existence of some species.

In comparison with many fish discussed above, distributions of most of the rare minnows considered in this Assessment are somewhat broader, but their populations have often been fragmented. For many minnow species, so little is known about requirements for various life stages that real threats and reasons for rarity are speculative. Dams, reservoirs, and other unknown factors have adversely altered habitat or water quality, resulting in isolated populations of some minnows, like the spotfin chub and blue shiner. Population augmentation or reintroduction may be necessary to improve the probability of long-term existence for some species.

Etnier and Starnes (1991) concluded that, although the madtoms are a disproportionately jeopardized part of Tennessee's fish, they are not largely confined to habitats that are more jeopardized than any others. Their specialized reproductive requirements and their probable sensitivity to trace chemicals ("olfactory noise;" see Etnier and Jenkins 1980) are likely major factors in their vulnerability. In addition, many of the madtoms included here, as well as the headwater catfish and the spotted bullhead, are narrow endemics, or currently exist as fragmented populations that are only portions of formerly more widespread geographic distributions. This habitat fragmentation also increases their vulnerability (Angermeier 1995). As with all species that have very limited ranges, any losses could be catastrophic, and could result from relatively minor accidents or events.

Sediment and pollutants that reduce the amount of available food or interfere with chemical communication could be detrimental to these catfish. In addition, although males protect eggs and young, chronic sedimentation can lead to heavy imbeddedness of the stream bottom, and greatly reduce the amount of suitable spawning sites. Measures that protect and improve habitat and water quality in streams where these fish are known to occur would increase the likelihood of their continued existence. Frequent, regular monitoring should be conducted, and population augmentation or reintroduction has been recommended for some species (Rakes and others 1999, Shute and others 1997).

Most of the rare sucker species included here are relatively large in comparison with the other groups of fishes discussed. The large number of individuals concentrated together during spawning runs and the noted quality of their flesh have made suckers a valuable food item for hundreds of years. Intensive harvesting by Native Americans and later by generations of Americans, however, apparently did not greatly reduce sucker populations. Only after the dams blocked their migration routes and altered flowing-river habitats did some sucker species experience declines. Postimpoundment declines may have resulted from overharvest because of the suckers being concentrated below the dams.

Suckers need an unconsolidated substrate for foraging. Chronic sedimentation causes stream bottoms to become imbedded with silt, making foraging more difficult and successful spawning less likely. In addition, nonnative predators, especially the flathead and blue catfish, decrease the survival of young suckers (NatureServe 2000). Measures to control sedimentation, careful management of nonnative fish, and, where appropriate, measures to assist in fish passage could ensure long-term survival of rare suckers.

The rare sturgeons are all large, long-lived fish. The very long period before reaching reproductive maturity and dams that block migration routes have led to declines. Most of the species discussed in this Assessment currently receive some form of Federal protection, either listing or candidate for listing, and they are not legally harvestable, although all sturgeons have historically been considered sport fish. Their continued survival will be contingent on reestablishing spawning runs and protecting immature fish. Like many large river mussels, these long-lived, big river fish may continue to exist, but if their habitats and migration routes have been destroyed, they may not persist without human intervention. In areas where appropriate habitats exist or are restored, reintroduction or population augmentation may be important management techniques for ensuring the long-term viability of these fishes.

The five live-bearers listed here are all narrowly endemic to warmwater springs. Two are either believed to be already extinct, and three are federally listed and in imminent danger of extinction. One was eliminated by the construction of a reservoir over its spring. The other was lost to herbicide pollution, competition, and eventual hybridization (NatureServe 2000). The other three live-bearers are currently facing these same threats, in addition to drawdown of the aquifers where they exist. The long-term survival of these species in the wild depends on managing the entire aquifers where the live-bearers occur, with careful consideration for the needs of these endemic fish.

The topminnows and studfish are also narrow endemics associated with a series of springs, or short stream sections. Ground-water drawdown has significantly impacted some of these fish, especially the Barrens topminnow. Collection for bait or aquarium trade may have also reduced the numbers of some populations, but was probably only a significant factor when droughts caused them to be concentrated in small areas. Captive breeding programs and long-term plans for water supply and use in the areas affecting these fishes would help to ensure their long-term survival.

The pygmy sunfish listed here are found in heavily vegetated springs, swamps, roadside ditches, and small streams. They are most vulnerable because of their short lifespan. Removing vegetation from the areas where they occur also threatens their continued existence.

The sculpins listed here are all narrow endemics found in small headwater streams or cold springs. Although the pygmy sculpin, found in a single spring, is potentially threatened by groundwater contamination and aquifer drawdown, the spring is used as a town water supply, and the fish is currently carefully monitored. However, because it is restricted to such a small geographic area, it is vulnerable.

The headwater sculpin species are threatened by commercial and residential development. Chronic sedimentation could reduce their food supply or interfere with reproduction. Although populations of these fish exist in small geographic areas, they are relatively abundant where they are found. Activities that improve or maintain habitat and water quality would help ensure their continued existence.

The bass are all narrow endemics. They are potentially threatened with hybridization or competition, to a lesser extent, with nonnative fish. Fishing pressure could affect these species.

The pupfish listed here are all narrow endemics. The three pupfish are endemic to small geographically isolated areas in Texas; two are restricted to springs where impoundments and aquifer drawdown have had significant adverse impacts (Elliott 2000, NatureServe 2000). Sheepshead minnows, not native to the areas where the pupfish are found, have been introduced and compete with or hybridize with all three species. Water pollution has also affected the Pecos pupfish. Potential for long-term survival of the two spring-inhabiting species of pupfish in the wild is low.

The cavefish are all narrow endemics. In addition to their endemism, the cavefish are threatened by life histories that result in extremely low population numbers (Hobbs 1992).

Chemical, nonpoint-source water pollution associated with agriculture and urban development could contribute to declines in these sensitive fish. Surface aquifer recharge areas may contribute chemicals that disrupt the essential chemoreception in blind cavefishes.

The Waccamaw silverside is restricted to Lake Waccamaw. Its short lifespan, just over 1 year, makes it vulnerable to unsuccessful spawning in a single season. The water quality in this lake is affected by nutrient loading from shoreline homes, agriculture, and intensive timber harvesting in the swamps surrounding the lake (Shute 1997). The recent natural invasion of the native brook silverside into Lake Waccamaw may pose a threat from competition to the Waccamaw silverside, but the likelihood of this is unknown at present [Personal communication. J.R. Shute (no personal communication information available at this time)].

The Alabama shad is a marine species that migrates into major rivers to spawn. Dams have blocked many rivers, preventing extensive spawning runs.

Amphibians—Dodd (1997) noted that, although some amphibian populations are known to fluctuate substantially from year to year, few long-term data sets exist to document whether this is a natural occurrence. As mentioned for other groups of aquatic animals, assessing conservation status is difficult without this information. Therefore, until better information is available, the list of rare amphibians included in this discussion should be considered only a representative sample of threatened species.

The 31 rare amphibians (table 23.9) include 2 frogs, 1 toad, and 28 salamanders (fig. 23.16). Two species (the toad and one salamander) are terrestrial as adults but lay their eggs in ephemeral ponds. The other 29

Table 23.9—The rare aquatic amphibians evaluated included 31 species, of which 5 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]
Ambystoma cingulatum	Flatwoods salamander	LT	G2G3	Ponds	Ponds
Amphiuma pholeter	One-toed amphiuma		G3	Ponds	Ponds
Bufo houstonensis	Houston toad	LE	G1	Ponds	Ponds
Desmognathus apalachicolae	Apalachicola dusky salamander		G3	Streams	Streams
Desmognathus carolinensis	Carolina Mountain dusky salamander		G2	Streams	Streams
Desmognathus imitator	Imitator salamander		G3	Streams	Streams
Desmognathus ocoee	Ocoee salamander		G2G3	Streams	Streams
Desmognathus orestes	Blue Ridge dusky salamander		G2	Streams	Streams
Eurycea latitans	Cascade Caverns salamander		G3	Ground water	Ground water
Eurycea nana	San Marcos salamander	LT	G1	Ground water	Ground water
Eurycea neotenes	Texas salamander		G1	Ground water	Ground water
Eurycea pterophila	Dwarf salamander		G2	Ground water	Ground water
Eurycea rathbuni	Texas blind salamander	LE	G1	Ground water	Ground water
Eurycea robusta	Blanco blind salamander		G1	Ground water	Ground water
Eurycea sosorum	Barton Springs salamander	LE	G1	Ground water	Ground water
Eurycea sp. 1	Plateau salamander		G1	Ground water	Ground water
Eurycea sp. 2	Salado Springs salamander		G1	Ground water	Ground water
Eurycea sp. 4	Buttercup Creek Caves salamander		G1	Ground water	Ground water
Eurycea sp. 5	Georgetown salamander		G1	Ground water	Ground water
Eurycea sp. 6	River spring salamander		G1	Ground water	Ground water
Eurycea tridentifera	Comal blind salamander		G1	Ground water	Ground water
Eurycea troglodytes	Valdina Farms sinkhole salamander		GH	Ground water	Ground water
Eurycea tynerensis	Oklahoma salamander		G3	Ground water	Ground water
Gyrinophilus palleucus	Tennessee cave salamander		G2	Ground water	Ground water
Haideotriton wallacei	Georgia blind salamander		G2	Ground water	Ground water
Necturus alabamensis	Black warrior waterdog		G2	Streams	Streams
Necturus lewisi	Neuse River waterdog		G3	Streams	Streams
Notophthalmus meridionalis	Black-spotted newt		G1	Ponds	Ponds
Notophthalmus perstriatus	Striped newt		G2G3	Ponds	Ponds
Pseudacris streckeri illinoensis	Illinois chorus frog		G5T3	Ponds	Ponds
Rana okaloosae	Florida bog frog		G2	Streams	Streams

ABI = Association for Biodiversity Information.
[a] Federal status: LE = listed as endangered; LT = listed as threatened.
[b] See table 23.1 for definitions of ABI rankings.
[c] Primary and secondary habitat do not necessarily imply a constistent order or ranking of importance to the taxonomic group.
Source: NatureServe 2000b.

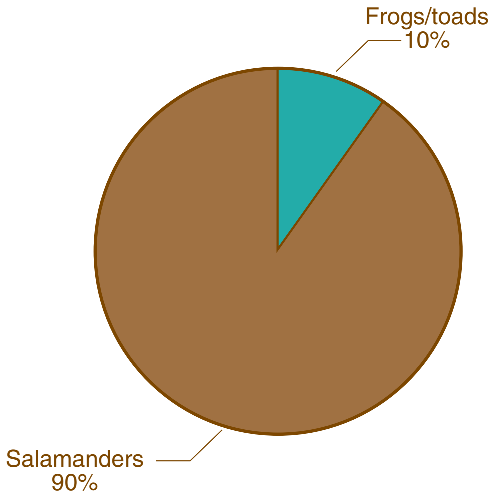


Figure 23.16—The 31 rare aquatic amphibians are dominated by salamanders; only 2 frogs and 1 toad are evaluated in this Assessment.

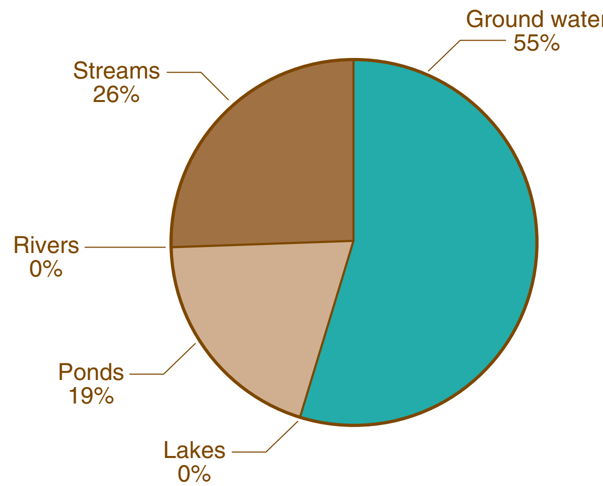


Figure 23.17—The 31 rare aquatic amphibians are reliant on 3 of the 5 habitats evaluated. No rare amphibians are dependent on river or lake habitats. Ground water systems support the most species.

species use the aquatic environment year round, including the breeding season. The primary habitats where these amphibians are found are shown in fig. 23.17. Rivers and lakes are not frequently used by any of the rare amphibians included here. Sixteen of the nineteen salamanders discussed are associated with subterranean streams and springs of the Edward's Aquifer in central Texas.

Most amphibians are predators feeding primarily on invertebrates as adults and larvae (tadpoles) (Petranka 1998). Female salamanders of some species protect their eggs. The frogs and toad lay their eggs in ponds and abandon them. The flatwoods salamander lays its eggs in areas that are likely to be temporarily flooded after heavy rains (Petranka 1998).

AQUATIC

The rare amphibians included in this Assessment are not distributed uniformly across the South. Figure 23.18 shows three significant clusters of amphibian occurrences. The first cluster is in central Texas, principally the Edward's Aquifer, where groundwater habitats support a variety of species. A second cluster along the Appalachian Mountains is the result of several geographically restricted salamander species associated with flowing streams and streamside habitats. A third concentration of rare amphibian occurrences extends across the Florida panhandle, where salamanders, newts, and an amphiuma are the species of concern. Dodd (1997) noted the same areas of importance, and included the Edward's Plateau and the Interior Highlands as important areas for amphibian diversity.

Threats to amphibians—Amphibians are subject to a variety of direct and indirect threats to survival, including bait collecting (Benz and Collins 1997, U.S. Department of Agriculture, Forest Service 2001), removal of mature hardwood trees along streams (Petranka 1998), intensive ground-disturbing activities associated with timber extraction (Petranka 1998, Petranka and others 1994), and acid rain (Petranka 1998). Dodd (1997) suggested that the different life-history stages (eggs, larvae, young, adults) might have different sensitivities to environmental perturbations.

Several rare amphibians primarily associated with perennial streams and streamside habitats are especially vulnerable because of their geographically restricted distributions (Petranka 1998). In addition, removing beaver has reduced the number of southern wetland habitats (Herrig and Bass 1998, White and Wilds 1997), further isolating many amphibian populations. Dodd (1997) also noted that if population fluctuations reported for some amphibians are natural, small, isolated populations might be especially at risk.

Subterranean species are sensitive to sedimentation and to seepage of even small quantities of chemicals or nutrients into the aquifers (Elliott 2000, Petranka 1998).

Amphibians associated with perennial streams and streamsides are affected by the removal of riparian vegetation; thus they would benefit from the careful management of appropriately sized buffer strips.

Amphibians associated with ephemeral ponds on the Atlantic and Gulf Coastal Plains are threatened by changes in hydrology brought on by intensified forest management and agricultural or urban development. In these areas, wetlands used by these amphibians are often altered by deliberately draining land with perched water tables (Miwa and others 1999, Segal and others 1987) or through indirect effects of other intensive land management activities (Palis 1996, Petranka 1998, Vickers and others 1985). Herbicides used in conjunction with timber harvests may also affect amphibians, but as with many other groups discussed here, sensitivity of amphibians to chemicals is largely unknown (Dodd 1997). Dodd (1997) noted that forest community changes associated with silvicultural activities such as conversion of deciduous forests to pine forests could result in reduced amphibian diversity.

Other factors that may affect rare amphibians include water-quality changes because of mining, acid precipitation, or runoff from road cuts. Changes in pH may have adverse effects, especially on eggs and larval stages, and can inhibit growth and feeding (Dodd 1997). Other chemical pollutants are known to mimic hormones, and thus may interfere with reproductive success (Dodd 1997). Ultraviolet light (UVB) is also

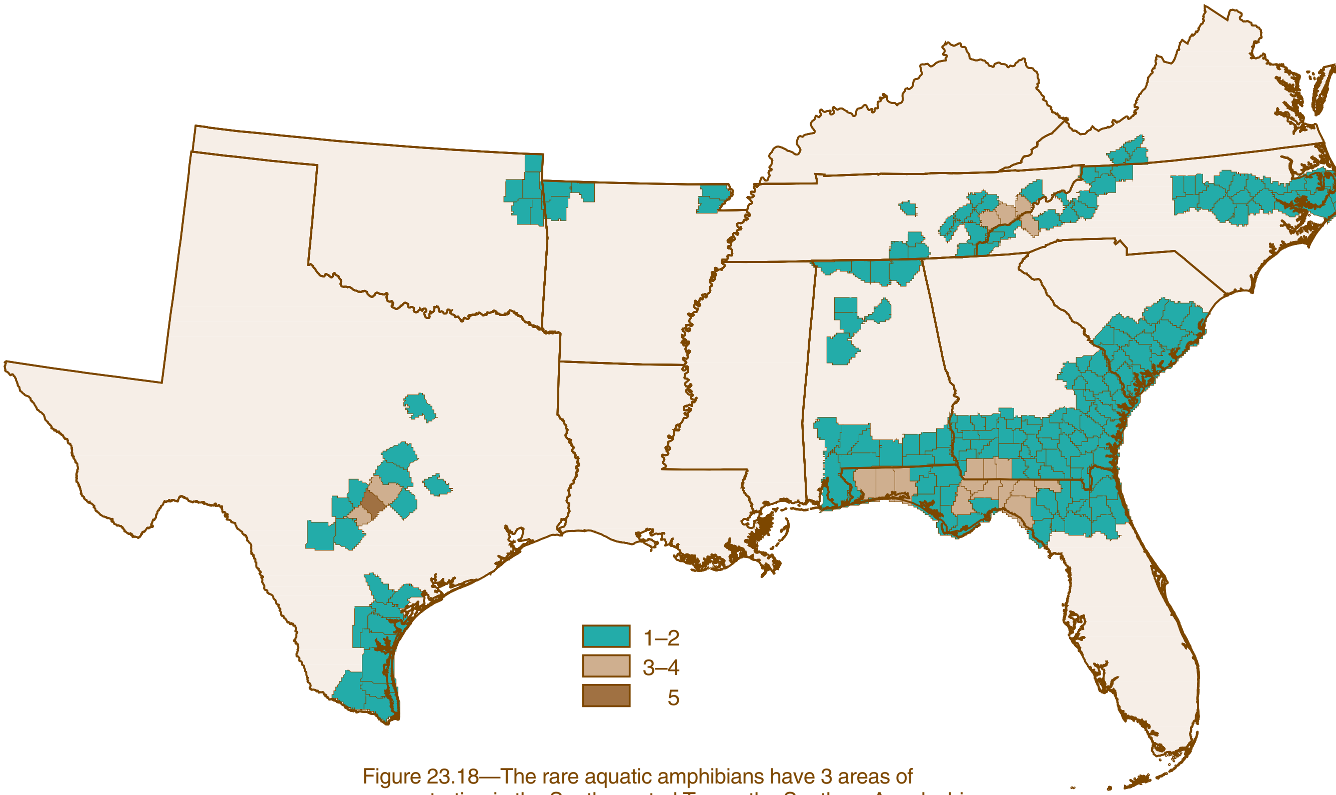


Figure 23.18—The rare aquatic amphibians have 3 areas of concentration in the South: central Texas, the Southern Appalachian Mountains, and the Panhandle of Florida.

known to affect larval hatching success. This effect is compounded by low pH (Dodd 1997).

Roads can have several adverse effects, including acting as barriers that prevent adults from migrating between nonbreeding and breeding habitats. Noise and light associated with roads may also interfere with the ability of frogs and toads to hear calls or to see and catch prey (Dodd 1997). Many rare amphibians use terrestrial habitats; they are discussed in chapters 1 and 5.

Future for amphibians—Sixteen of the nineteen salamanders included here are associated with subterranean streams and springs. These species are dependent on the Edward's Aquifer in central Texas and are affected by rapid agricultural and urban growth in this area. Although the only known location for the Valdina Farms sinkhole salamander has been flooded by a reservoir, and the species may no longer exist (NatureServe 2000), the more common threat to the salamanders in this region is water withdrawal from Edward's Aquifer.

Three additional subterranean or spring-associated salamanders are included in this Assessment. One is known from northern Oklahoma and Arkansas, another from southern Tennessee and northern Alabama, and the third from southwestern Georgia and northern Florida. All three of these species are apparently far less threatened than are their Texas counterparts. However, like other subterranean species, sedimentation and seepage of even small quantities of chemicals or nutrients into the aquifers could pose significant threats to their continued existence (Petranka 1998).

The amphibians associated with perennial streams and streamsides include six salamanders restricted to small geographic areas in the Southern Appalachian Mountains, two salamanders and a frog restricted to the Gulf Coastal Plain, and a salamander from the Atlantic Coastal Plain in North Carolina. Because of their restricted ranges, these amphibians are all vulnerable to relatively small disturbances, which may further isolate populations. Perturbations could result from intensive ground-disturbing activities associated with timber harvesting, altering wetlands, and stream sedimentation (Petranka 1998).

Herrig and Bass (1998) demonstrated the importance of the dispersal mechanism that beaver ponds provided to amphibians, prior to the beaver's extirpation in the 1700s. Because of the greatly diminished riparian habitat provided by beavers, gene dispersal between salamander populations is restricted in some areas. Another threat is the collection of salamanders for bait (Petranka 1998), which often happens with little regard to species. Acid precipitation and sedimentation in streams may also contribute to the decline of some salamanders in this region. All six of these stream-dwelling salamanders are located primarily on land administered by the National Park Service and the USDA Forest Service.

Three rare salamanders and a frog are associated with perennial streams and streamsides near the Gulf and Atlantic Coasts. They are most affected by the removal of riparian vegetation. In addition, as discussed earlier, the small number of beaver ponds present in these areas restricts gene flow between populations. Maintenance of streamside buffers would increase the likelihood of long-term existence of these amphibians.

The final group of amphibians includes four salamanders, a frog, and a toad, all of which are associated with ephemeral ponds. Land management activities that result in rapid runoff instead of retention of standing pools of water are detrimental to these species. For example, the flatwoods salamander and the Houston toad have suffered significant range reductions brought on by certain land management activities, including land clearing, ditching, draining and filling of wetlands, and hydrological alteration brought on by mechanical disturbance of the soil (Jensen 1999, NatureServe 2000, Petranka 1998). Restoring and protecting important ephemeral ponds may be necessary to ensure the continued existence of the flatwoods salamander (U.S. Federal Register, April 1, 1999). Land uses that alter habitats required by the flatwoods salamander threaten the species.

The Texas Parks and Wildlife Department now manages two preserves for the recovery of the Houston toad (Fostey 2001), which should ensure the survival of this species, at least for the short term. The other four remaining species of ephemeral pond-dwelling amphibians (three salamanders and one frog) have apparently not been affected as severely as those discussed earlier.

Reptiles—Although Buhlmann and Gibbons (1997) reported that historical information needed to accurately determine the status of many North American aquatic reptiles is lacking, they concluded that more than half of the southeastern aquatic reptile fauna is jeopardized. Because of this lack of information, the list included in this Assessment should probably be considered as only an indicator of the trends in southeastern aquatic reptile status. However, Buhlmann and Gibbons (1997) noted that the Southeast contains North America's greatest diversity of freshwater turtles.

The 19 rare reptiles (table 23.10) discussed here include 1 crocodile, 4 snakes, and 14 turtles (fig. 23.19). These reptiles are typically found in flowing rivers or calm waters of swamps and bogs (fig. 23.20); none are known to depend on groundwater habitats or lake habitats. Most of these reptiles require basking sites such as logs or boulders that protrude from the water. Except for the live-bearing snakes of the genus *Nerodia*, all of these reptiles require undisturbed gravel bars or soft banks for egg laying (Wilson 1995). Most of these rare reptiles are long-lived and require several years to reach sexual maturity (White and Wilds 1997).

Invertebrates, fish, and amphibians are their main food items. An exception is the Alabama redbelly turtle, an herbivore that feeds on aquatic plants (NatureServe 2000, U.S. Department of the Interior, Fish and Wildlife Service 2000, Wilson 1995).

Two areas in the South are known to have concentrations of rare reptiles (fig. 23.21). One area in west Texas

Table 23.10—The rare aquatic reptiles evaluated included 19 species, of which 8 are federally listed as threatened or endangered

Scientific name	Common name	Federal status[a]	ABI global rank[b]	Primary habitat[c]	Secondary habitat[c]
Clemmys muhlenbergii	Bog turtle	LT	G3	Ponds	Ponds
Crocodylus acutus	American crocodile	LE	G2	Ponds	Rivers
Farancia erytrogramma seminola	South Florida rainbow snake		G5T1	Streams	Ponds
Graptemys barbouri	Barbour's map turtle		G2	Streams	Rivers
Graptemys caglei	Cagle's map turtle	C	G3	Streams	Rivers
Graptemys ernsti	Escambia map turtle		G2	Rivers	Ponds
Graptemys flavimaculata	Yellow-blotched map turtle	LT	G2	Rivers	Ponds
Graptemys nigrinoda	Black-knobbed map turtle		G3	Streams	Rivers
Graptemys nigrinoda delticola	Delta map turtle		G3T2	Streams	Rivers
Graptemys nigrinoda nigrinoda	Black-knobbed map turtle		G3T3	Streams	Rivers
Graptemys oculifera	Ringed map turtle	LT	G2	Rivers	Rivers
Kinosternon hirtipes	Mexican mud turtle		G3	Rivers	Ponds
Kinosternon hirtipes murrayi	Big Bend mud turtle		G3T3	Rivers	Ponds
Nerodia erythrogaster neglecta	Copperbelly water snake	LT	G5T2T3	Streams	Ponds
Nerodia harteri	Brazos water snake		G2	Streams	Ponds
Nerodia paucimaculata	Concho water snake	LT	G2	Streams	Ponds
Pseudemys alabamensis	Alabama redbelly turtle	LE	G1	Rivers	Rivers
Sternotherus depressus	Flattened musk turtle	LT	G2	Streams	Rivers
Trachemys gaigeae	Big bend slider		G3	Rivers	Rivers

ABI = Association for Biodiversity Information.
[a] Federal status: LE = listed as endangered; LT = listed as threatened; C = candidate for listing.
[b] See table 23.1 for definitions of ABI rankings.
[c] Primary and secondary habitat do not necessarily imply a constistent order or ranking of importance to the taxonomic group.
Source: NatureServe 2000b.

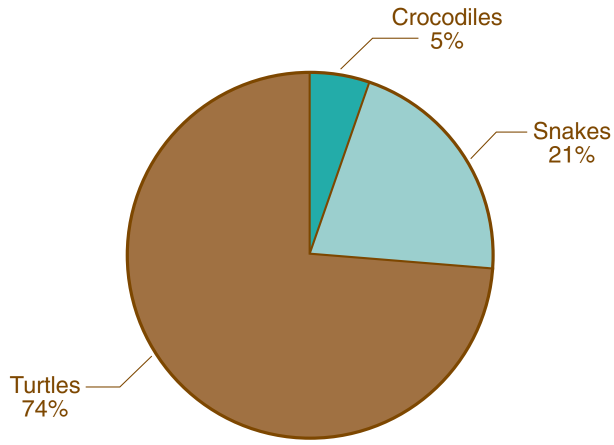


Figure 23.19—The 19 rare aquatic reptiles include 1 crocodile, 4 snakes, and 15 turtles.

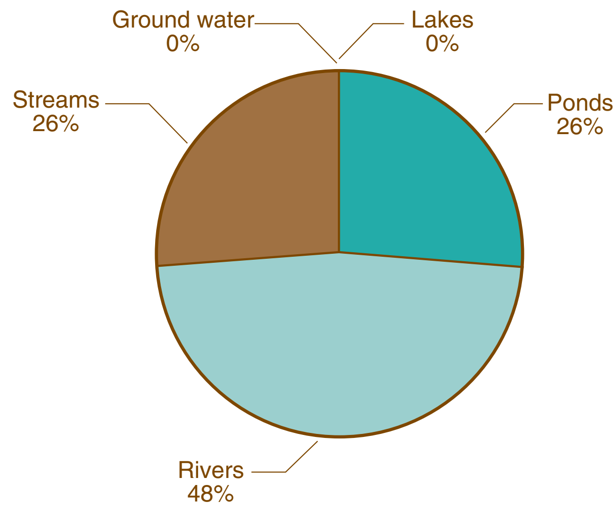


Figure 23.20—Almost one-half of the 19 rare aquatic reptiles are associated with rivers. Streams and ponds provide habitat for the remaining species. No rare aquatic reptile species are dependent on ground water and lake systems.

includes the Rio Grande and Pecos River systems, and another extends from central and southern Mississippi into the panhandle of Florida (fig. 23.21) (NatureServe 2000). Other rare reptile occurrences are scattered throughout southern Florida, the Southern Appalachian Mountains, western Tennessee and Kentucky, and central Texas (Wilson 1995).

Threats to reptiles—Many rare reptiles are long-lived, narrow endemics (Palmer and Braswell 1995, Wilson 1995) and are subject to extinction from natural chance events or even localized human activities. Seemingly inconsequential activities, such as riding an off-road vehicle on a stream-bank, collecting a few turtle eggs for the pet trade, or "plinking" at basking turtles, may in fact be devastating to species whose populations are isolated and which may have already experienced severe population declines. However, in comparison with the other aquatic animals included in this Assessment, these reptiles may be relatively resilient to or capable of adapting to habitat changes (NatureServe 2000). Buhlmann and Gibbons (1997) emphasized the lack of ecological knowledge about many aquatic reptiles; they could be more vulnerable than we know. Certain aspects of their life histories could be easily disrupted, resulting in population declines. Two species that are not narrowly endemic are the copperbelly water snake and bog turtle, which both have relatively widespread but

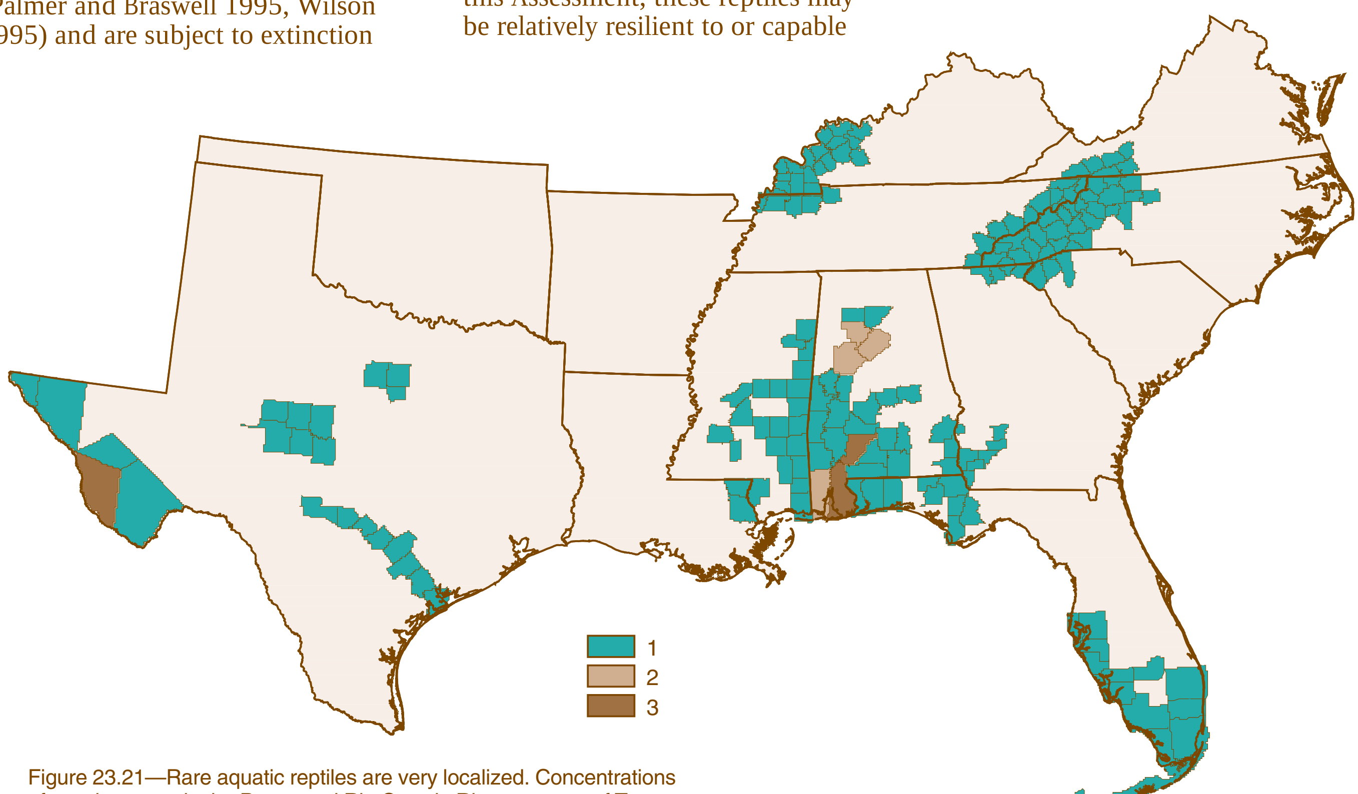


Figure 23.21—Rare aquatic reptiles are very localized. Concentrations of species occur in the Pecos and Rio Grande River systems of Texas and in the Mobile and Mississippi River basins.

spotty distributions. Thus, they are also subject to extinction from natural chance events or localized human activities.

The illegal pet trade also could have a significant impact on some of these reptile populations (Buhlmann and Gibbons 1997), especially those of small turtles. Overharvest for food (largely for Asian markets) could have significant impacts on some turtles. Some harvest is apparently legal, but poorly regulated (Buhlmann and Gibbons 1997). Target practice results in the death or injury of many rare turtles and snakes (NatureServe 2000).

Pollution and sediment may impact all of these species directly or indirectly through a reduction in their food organisms (NatureServe 2000). The 16 egg-laying species are potentially affected by direct disturbances to their nests (Conant and Collins 1998). Most nests are close to water; the eggs often remain buried for months. Off-road vehicle riding, trampling, or other human activities could destroy these nests (NatureServe 2000).

The reptiles that prefer flowing water have been impacted by dams, channelization, and dredging (NatureServe 2000). These activities often remove logs that extend out of the water, which are essential basking sites. The Texas species have also been impacted by water withdrawal (NatureServe 2000).

The species that prefer standing water in bogs or swamps have lost habitat because of wetland alterations, removal of basking logs, and loss of beaver ponds (Herrig and Bass 1998, NatureServe 2000).

Future for reptiles—The loss of beaver and the wetlands they create has greatly reduced the available habitat for bog turtles and copperbelly water snakes. Natural range expansion and genetic dispersal for these species requires an interconnection of suitable aquatic habitats (Herrig and Bass 1998). However, since beaver are increasing in the South, these situations may improve.

Removing water for irrigation, industrial, and urban uses; lowering stream flows; and pollution resulting from agricultural practices have contributed to the decline of rare aquatic reptiles in Texas (NatureServe 2000). Development and implementation of management plans to provide appropriate amounts and quality of water would increase the long-term survival potential for these species.

Identification and protection of important nesting areas along waterways would improve the future prospects of these long-lived reptiles.

Summary Conclusions

Presently, the major threats to our southern aquatic animals include population fragmentation resulting from impoundments and other habitat alterations, sedimentation, and pollutants. Other threats include homogenization of the aquatic communities, resulting from species introductions, and interbasin connections. Grumbine (1990) noted difficulties in conserving rare species: “Providing for viable populations of native species on Federal lands will require some unprecedented combinations of administrative and legal reform.” Grumbine considered restoring natural fire cycles, reintroducing extirpated and endangered species, closing roads, and reforestation as important components of this reform.

The extraordinary diversity of aquatic animals in the Southeastern United States still exists today in spite of the many threats to their environments. Sustaining these animals and their habitats will require surmounting many difficult challenges.

Needs for Additional Research

Benz and Collins (1997) summarized “Southeastern Aquatic Fauna in Peril: The Southeastern Perspective” and noted several recurrent themes for all groups of southeastern aquatic animals. These themes are discussed in this Assessment and summarized by Shute and others (1997). For example, distributional information is relatively well documented for most southern fish, but there are still gaps in our knowledge. Even less is known about the other aquatic animal groups included here. Baseline information is necessary to document declines and to predict extirpations and extinctions.

General distribution information and long-term population data are not presently available for any aquatic animal groups. These data would help in predicting extinctions (Angermeier 1995, Etnier 1994, Lydeard and Mayden 1995). Grumbine (1990) also noted insufficient knowledge of population dynamics.

Life history and habitat preferences are critically needed for all life stages of all the aquatic animal groups discussed here, especially the aquatic insects. Several authors have emphasized that different life stages (eggs, larvae, juveniles) may have different habitat requirements that could explain their vulnerability. Rakes and others (1999) provided some examples of previously unknown habitat requirements and life-history habits of larval boulder darters and spotfin chubs that could explain their sensitivity. O'Dee and Watters (2000) commented that proper identification of host fish species for rare mussels would provide information needed by resource agencies to manage for preservation or conservation of rare mussels.

Other authors (Dodd 1997, Neves and others 1997, Shute and others 1997) suggested that early life-history stages of mussels, amphibians, and fishes might be more sensitive to various pollutants than adults are. To ensure that water-quality standards are adequate to protect the more sensitive animals, toxicity testing of rare animals or their surrogates has been recommended by these authors.

Etnier and Starnes (1991) noted that fish found in springs and medium-sized rivers were disproportionately jeopardized. They suggested that this conclusion be documented by studying other groups of aquatic animals found in these habitat types.

The information recommended here will be of little use if it is not made available to those who should use it. Grumbine (1990) recommended constructing a regional database of species of concern that would include information on habitat requirements, reserves, connectivity, zoning, buffers, and ecological restoration. Some of this information already exists in various places (NatureServe and Natural Heritage programs, for example), but appropriately interpreted versions could be made available for various types of users. This Assessment is intended to be a step in that direction.

Finally, captive propagation techniques need to be developed for some mussels (Neves and others 1997) and fish (Rakes and others 1999). Reintroductions and population augmentation may help to restore or manage populations of declining animals. For example, mussels are being reintroduced into main stem riverine habitats in the Tennessee River (U.S. Federal Register 2001a). Similar proposals are underway for fish (U.S. Federal Register 2001b). In some situations, reintroductions may be appropriate for sensitive species that cannot invade these restored or improved areas (Dunn and others 2000).

Literature Cited

Abell, Robin A.; Olson, David M.; Dinerstein, Eric [and others]. 2000. Freshwater ecoregions of North America: a conservation assessment. Washington, DC: Island Press. 319 p.

Ahlstedt, Steve. 1983. Recovery plan for the green-blossom pearly mussel *Epioblasma (=Dysnomia) torulosa gubernaculums* (Reeve, 1865). Atlanta: U.S. Department of the Interior, U.S. Fish and Wildlife Service. 50 p.

Angermeier, P.L. 1995. Ecological attributes of extinction-prone species: loss of freshwater fishes of Virginia. Conservation Biology. 9: 143–158.

Benke, A.C. 1990. A perspective on America's vanishing streams. Journal of the North American Benthological Society. 9: 77–88.

Benz, G.W.; Collins, D.E. 1997. Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeast Aquatic Research Institute, Lenz Design and Communications. 554 p.

Bogan, Arthur E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): a search for causes. American Zoology. 33: 599–609.

Buhlmann, K.A.; Gibbons, J.W. 1997. Imperiled aquatic reptiles of the Southeastern United States: historical review and current conservation status. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 201–232.

Burr, B.M.; Stoeckel, J.N. 1999. The natural history of madtoms (genus *Noturus*), North America's diminutive catfishes. American Fisheries Society Symposium. 24: 51–101.

Burr, Brooks M.; Warren, Melvin L., Jr. 1986. A distributional atlas of Kentucky fishes. Frankfort, KY: Kentucky Nature Preserves Commission. 398 p.

Coats, R.N.; Miller, T.O. 1981. Cummulative silvicultural impacts on watersheds: a hydrologic and regulatory dilemma. Environmental Management. 5: 147–160.

Conant, Roger; Collins, Joseph T. 1998. A field guide to reptiles and amphibians; Eastern and Central North America. Boston: Houghton Mifflin Co. 616 p.

Crisman, T.C. 1992. Natural lakes of the Southeastern United States: origin, structure, and function. In: Hackney, C.T.; Adams, S.M.; Martin, W.H., eds. Biodiversity of the Southeastern United States: aquatic communities. New York: John Wiley: 475–538.

Davis, J.; Hurst, R.; Goranflo, M., Jr.; Whitlock, A. 2001. A river runs through it. Forum for Applied Research and Public Policy. 16: 103–108.

Dennis, Sally D. 1985. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting factors of siltation. Nashville, TN: Tennessee Wildlife Resources Agency. 85(2): 171.

Dodd, C.K., Jr. 1997. Imperiled amphibians, a historical perspective. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 165–200.

Dunn, H.L.; Sietman, B.E.; Kelner, D.E. 2000. Evaluation of recent unionid (Bivalvia) relocations and suggestions for future relocations and reintroductions. In: Tankersley, R.A.; Warmolts, D.I.; Watters, G.T. [and others], eds. Proceedings, freshwater mollusk symposium. Columbus, OH: Ohio Biological Survey: 169–189.

Elliott, W.R. 2000. Conservation of the North American cave and karst biota. In: Wilkens, H.; Culver, D.C.; Humphreys, W.F., eds. Subterranean ecosystems. [Place of publication unknown]: [Publisher unknown]. [Number of pages unknown].

Etnier, D.A. 1994. Our southeastern fishes—what have we lost and what are we likely to lose. Proceedings: southeastern fishes council. [Place of publication unknown]: [Publisher unknown]. 29: 5–9.

Etnier, D.A. 1997. Jeopardized southeastern freshwater fishes: a search for causes. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 87–104.

Etnier, D.A.; Jenkins, R.E. 1980. *Noturus stanauli*, a new madtom catfish (Ictaluridae) from the Clinch and Duck Rivers, Tennessee. Bulletin of the Alabama Museum of Natural History. 5: 17–22.

Etnier, D.A.; Starnes, W.C. 1991. An analysis of Tennessee's jeopardized fish taxa. Journal of the Tennessee Academy of Science. 66: 129–133.

Etnier, D.A.; Starnes, W.C. 1993. The fishes of Tennessee. Knoxville, TN: The University of Tennessee Press. 681 p.

Fostey, Nathan. 2001. *Bufo houstonensis* Houston toad. Lansing, MI: University of Michigan Press. 23 p.

Fridell, John A. 1996. Recovery plan for Appalachian elktoe *(Alasmidonta ravelinana)* Lea. Atlanta: U.S. Department of the Interior, Fish and Wildlife Service. 48 p.

Grumbine, E. 1990. Viable populations, reserve size, and Federal l ands management: a critique. Conservation Biology. 4: 127–134.

Harris, S.C.; O'Neil, P.E.; Lago, P.K. 1991. Caddisflies of Alabama, 1991. Bull. 145. Tuscaloosa, AL: Geological Survey of Alabama. 442 p.

Hart, C.W., Jr.; Fuller, Samuel L.H. 1974. Pollution ecology of freshwater invertebrates. New York: Academic Press. 312 p.

Herrig, Jim; Bass, Quentin. 1998. Beaver: the light in the forest. In: SAMAB, ninth annual conference. On file with: Jim Herrig, Cherokee National Forest, P.O. Box 2010, Cleveland, TN 37320.

Hobbs, H.H., Jr. 1976. Crayfishes (Astacidae) of North and Middle America. Res. Ser. 18050 ELD05/72. Cincinnati, OH: U.S. EPA, Water Pollution Control. 173 p. [2d printing].

Hobbs, H.H., Jr. 1981. The crayfishes of Georgia. Smithsonian Contributions to Zoology. 318: 1–549.

Hobbs, H.H., III. 1992. Caves and springs. In: Biodiversity of the Southeastern United States: aquatic communities. New York: John Wiley: 59–131.

Hobbs, Horton H., Jr. 1989. An illustrated checklist of the American crayfishes (Decapoda: Astacidae, Cambaridae and Parastaeidae). Washington, DC: Smithsonian Contributions to Zoology. 480. 236 p.

Hubbs, C. 1995. Springs and spring runs as unique aquatic systems. Copeia. 1995: 989–991.

Hughes, M.H.; Parmalee, P.W. 1999. Prehistoric and modern freshwater mussel (Mollusca: Bivalvia: Unionidae) faunas of the Tennessee River: Alabama, Kentucky, and Tennessee. Regulated Rivers: Research & Management. 15: 25–42.

Jenkins, Robert E.; Burkhead, Noel M. 1993. Freshwater fishes of Virginia. Bethesda, MD: American Fisheries Society. 1,079 p.

Jenkinson, J.J.; Todd, R.M. 1997. Management of native mollusk resources. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective: Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 283–305.

Jensen, J.B. 1999. Flatwoods salamander. In: Protected animals of Georgia. Social Circle, GA: Georgia Department of Natural Resources: 92–93.

Johnson, Waynon W.; Finley, Mack T. 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. Resour. Publ. 137. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 93 p.

Layzer, J.B.; Gordon, M.E.; Anderson, R.M. 1993. Mussels: the forgotten fauna of regulated rivers: a case study of the Caney Fork River. Regulated Rivers. 8: 63–71.

Lee, David S.; Gilbert, C.R.; Hocutt, C.H. [and others]. 1980. Atlas of North American freshwater fishes. Raleigh, NC: North Carolina State Museum of Natural History. 854 p.

Lydeard, C.; Mayden, R.L. 1995. A diverse and endangered aquatic ecosystem of the Southeastern United States. Conservation Biology. 9: 800–805.

Master, L.L.; Flack, S.R.; Stein, B.A. 1998. Rivers of life: critical watersheds for protecting freshwater biodiversity. Arlington, VA: The Nature Conservancy. 71 p.

Mayer, Foster L., Jr.; Ellersick, Mark R. 1986. Manual of aquatic toxicology: interpretation and data-base for 410 chemicals and 66 species of freshwater animals. Resour. Publ. 160. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 579 p.

McGregor, S.W.; Shepard, T.E. 1995. Investigations of slackwater darter, *Etheostoma boschungi*, populations, 1992–1994. Circ. 184. Tuscaloosa, AL: Geological Survey of Alabama. 33 p.

Meritt, R.W.; Cummins, K.W. 1984. An introduction to the aquatic insects of North America. 2d ed. Dubuque, IA: Kendall Hunt. [Number of pages unknown].

Mettee, M.F.; O'Neil, P.E.; Pierson, J.M. 1996. Fishes of Alabama and the Mobile Basin. Birmingham, AL: Oxmoor House. 820 p.

Mishall, G.W.; Petersen, R.C.; Cummings, K.W. [and others]. 1983. Interbiome comparison of stream ecosystem dynamics. Ecological Monographs. 53: 1–25.

Miwa, Masato; Aust, W. Michael; Burger, James A. [and others]. 1999. Harvesting and site preparation effects on the hydroperiods or wet pine plantations. In: Haywood, James D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 293–297.

Morse, J.C.; Stark, B.P.; McCafferty, W.P.; Tennessen, K.J. 1997. Southern Appalachian and other southeastern streams at risk: implications for mayflies, dragonflies and damselflies, stoneflies, and caddisflies. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 17–42.

NatureServe. 2000. An online encyclopedia of life. [Database]. Version 1.1. Arlington, VA: Association for Biodiversity Information. http://www.natureserve.org/. [Date accessed: May 16].

NatureServe. 2001. An online encyclopedia of life. [Database]. Version 1.5. Arlington, VA: Association for Biodiversity Information. http://www.natureserve.org/. [Date accessed: July 15].

Neves, R.J.; Bogan, A.E.; Williams, J.D. (and others). 1997. Status of aquatic mollusks in the Southeastern United States: a downward spiral of diversity. In: Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeast Aquatic Research Institute, Lenz Design and Communications. [Number of pages unknown].

Nico, L.G.; Fuller, P.L. 1999. Spatial and temporal patterns of nonindigenous fish introductions in the United States. Fisheries. 24: 16–27.

O'Dee, S.H.; Watters, G.T. 2000. New or confirmed host identifications for ten freshwater mussels. In: Tankersley, R.A.; Warmolts, D.I.; Watters, G.T. [and others], eds. Proceedings, freshwater mollusk symposium. Columbus, OH: Ohio Biological Survey: 77–82.

Palis, J.G. 1996. Flatwoods salamander (*Ambystoma cingulatum* Cope). Element stewardship [Abstract]. Natural Areas Journal. 16: 49–54.

Palmer, William M.; Braswell, Alvin L. 1995. Reptiles of North Carolina. Chapel Hill, NC: The University of North Carolina Press. 412 p.

Parmalee, Paul W.; Bogan, Arthur E. 1998. The freshwater mussels of Tennessee. Knoxville, TN: The University of Tennessee Press. 328 p.

Peck, S.B. 1998. A summary of diversity and distribution of the obligate cave-inhabiting faunas of the United States and Canada. Journal of Cave and Karst Studies. 60: 18–26.

Pennak, Robert W. 1989. Freshwater invertebrates of the United States. 3rd ed. New York: John Wiley. 628 p.

Petranka, J.W.; Brannon, M.P.; Hopey, M.E. [and others]. 1994. Effects of timber harvesting on low elevation populations of Southern Appalachian salamanders. Forest Ecology and Management. 67: 135–147.

Petranka, James W. 1998. Salamanders of the United States and Canada. Washington; London: Smithsonian Institution Press. 587 p.

Pflieger, William L. 1975. The fishes of Missouri. Jefferson City, MO: Missouri Department of Conservation. 343 p.

Pflieger, William L. 1996. The crayfishes of Missouri. Jefferson City, MO: Missouri Department of Conservation. 152 p.

Rakes, P.L.; Shute, J.R.; Shute, P.W. 1999. Reproductive behavior, captive breeding, and restoration ecology of endangered fishes. Environmental Biology of Fishes. 55: 31–42.

Rand, Gary M.; Petrocelli, S.R. 1985. Fundamentals of aquatic toxicology. New York: Hemisphere Publishing Corp. 666 p.

Ricciardi, A.; Rasmussen, J.B. 1999. Extinction rates of North American freshwater fauna. Convservation Biology. 13: 1220–1222.

Richter, B.D.; Braum, D.P.; Mendelson, M.A. [and others]. 1997. Threats to imperiled freshwater fauna. Conservation Biology. 11: 1081–1093.

Rohde, F.C.; Arndt, R.G. 1987. Two new species of pygmy sunfishes (Elassomatidae, *Elassoma*) from the Carolinas. Proceedings of the Academy of Natural Sciences. 139: 65–85.

Ryon, M.G. 1986. The life history and ecology of *Etheostoma trisella* (Pisces: Percidae). American Midland Naturalist. 115: 73–86.

Schuster, G.A. 1997. Resource management of freshwater crustaceans in the Southeastern United States. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective. Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 269–282.

Segal, D.S.; Neary, D.G.; Best, G.R.; Michael, J.L. 1987. Effect of ditching, fertilizing, and herbicide application on groundwater levels and groundwater quality in a flatwood spodsol. In: Proceedings, Soil and Crop Science Society of Florida. Florida Agric. Exp. Stn. J. Ser. 7942. [Place of publication unknown]: [Publisher unknown]. 46: 107–112.

Sheldon, A.E. 1988. Conservation of stream fishes: patterns of diversity, rarity, and risk. Conservation Biology. 2: 149–156.

Shelton, Douglas N. 2000a. A systematic list of mollusks in the northern Gulf of Mexico off the coast of Alabama. [Database]. http://home.hiwaay.net/~dwills/alaview.html. [Date accessed: August 24].

Shelton, Douglas N. 2000b. A systematic list of terrestrial mollusks from the State of Alabama. [Database]. http://home.hiwaay.net/~dwills/alaview.html. [Date accessed: August 24].

Shute, J.R. 1997. Waccamaw silverside *Menidia extensa* Hubbs and Raney. In: Endangered, threatened, and rare fauna of North Carolina. Part IV. A reevaluation of the freshwater fishes. Occas. Pap. [Raleigh, NC]: North Carolina State Museum of Natural Sciences; North Carolina Biological Survey. 11: 106 p.

Shute, P.W.; Biggins, R.G.; Butler, R.S. 1997. Management and conservation of aquatic resources: a historical perspective and recommendations for incorporating ecosystem management. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective.Spec. Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 445–466.

Skelton, C.E. 2001. New dace of the genus *Phoxinus* (Cyprinidae: Cypriniformes) from the Tennessee River Drainage, Tennessee. Copeia. 2001: 118–128.

Smith-Vaniz, William F. 1968. Freshwater fishes of Alabama. Auburn, AL: Auburn University. 211 p.

Stein, B.A.; Kutner, L.S.; Adams, J.S. 2000. Precious heritage: the status of biodiversity in the United States. New York: Oxford University Press. 399 p.

Taylor, C.A.; Warren, M.L., Jr.; Fitzpatrick, J.F., Jr. [and others]. 1996. Conservation status of crayfishes of the United States and Canada. Fisheries. 21(4): 25–38.

Thoma, R.F. 2000. *Cambaraus* (*Jugicambarus*) *jezerinaci* (Crustacea: Decapoda: Cambaridae), a new species of crayfish from the Powell River drainage of Tennessee and Virginia. Proceedings of the Biological Society of Washington. 113: 731–738.

Thompson, Fred G. 2000. Field guide to the freshwater snails of Florida. http://www.flmnh.ufl.edu/natsci/malacology/fl-snail/snails7.htm [Date accessed: August 24].

Todd, J.H. 1973. The chemical language of fishes. Scientific American. 224: 99–108.

Ungate, Christopher D. 1990. Final environmental impact statement: Tennessee River and reservoir system operation and planning review. TVA/RDG/Eqs-91/1. Knoxville, TN: [Publisher unknown]. 198 p.

U.S. Department of Agriculture, Forest Service. 1989. Final environmental impact statement: vegetation management in the Appalachian Mountains. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 331 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1992. Endangered and threatened species of the Southeastern United States (the red book). Atlanta: U.S. Department of the Interior, Fish and Wildlife Service. [Not paged].

U.S. Department of the Interior, Fish and Wildlife Service. 2000. Mobile River Basin aquatic ecosystem recovery plan. Atlanta: U.S. Department of the Interior, Fish and Wildlife Service. 128 p.

U.S. Federal Register. December 18, 1997. Final rule to list three aquatic invertebrates in Comal and Hays Counties, TX as endangered. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service: 62(243): 66,295–66,304. http://www.access.gpo.gov/su_docs/aces/aces140.html. [Date accessed: August 23, 2002].

U.S. Federal Register. April 1, 1999. Final rule on listing the flatwoods salamander. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 64(62): 15,691–15,704. http://www.access.gpo.gov/su_docs/aces/aces140.html. [Date accessed: August 23, 2002].

U.S. Federal Register. 2001a. Endangered and threatened wildlife and plants; establishment of nonessential experimental population status for 16 freshwater mussels and 1 freshwater snail (Anthony's riversnail) in the free-flowing reach of the Tennessee River below the Wilson Dam, Colbert and Lauderdale Counties, AL. [Washington, DC]: [U.S. Department of the Interior, Fish and Wildlife Service]. 66: 32,250–32,264. http://www.access.gpo.gov/su_docs/aces/aces140.html. [Date accessed: August 23, 2002].

U.S. Federal Register. 2001b. Endangered and threatened wildlife and plants; proposed establishment of nonessential experimental population status for 4 fishes into the Tellico River, from the backwaters of Tellico Reservoir upstream to Tellico River mile 33 in Monroe County, Tennessee. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 66(111): 30,853–30,860. http://www.access.gpo.gov/su_docs/aces/aces140.html. [Date accessed: August 24, 2002].

Vannote, R.L.; Minshall, G.W.; Cummings, K.W. [and others]. 1980. The river continuum concept. Canada Journal of Fisheries & Aquatic Sciences. 37: 130–137.

Vickers, C.R.; Harris, L.D.; Swindel, B.F. 1985. Changes in herpetofauna results from ditching of cypress ponds in Coastal Plains flatwoods. Forest Ecology and Management. 11: 17–29.

Wallace, J.T.; Webster, J.R.; Lowe, R.L. 1992. High gradient streams of the Appalachians. In: Biodiversity of the Southeastern United States, aquatic communities. New York: John Wiley: 133–191.

Warren, M.L., Jr.; Angermeier, P.L.; Burr, B.M.; Haag, W.R. 1997. Decline of a diverse fish fauna: patterns of imperilment and protection in the Southeastern United States. In: Benz, G.W.; Collins, D.E., eds. Aquatic fauna in peril: the southeastern perspective. Spec.Publ. 1. Decatur, GA: Southeastern Aquatic Research Institute, Lenz Design and Communications: 105–164.

Warren, Melvin L., Jr.; Burr, B.M.; Walsh, S.J. [and others]. 2000. Diversity, distribution, and conservation status of the native freshwater fishes of the Southeastern United States. Fisheries. 25(10): 7–29.

Welch, Paul S. 1952. Limnology. New York: McGraw-Hill. 538 p.

White, P.S.; Wilds, S.P. 1997. Status and trends of the Nation's biological diversity. Fort Collins, CO: U.S. Department of the Interior, Geological Survey. 1: 255–313.

Wiggins, B.G. 1977. Larvae of the North American caddisfly genera (Trichoptera). Toronto: University of Toronoto Press. 457 p.

Wilcove, D.S.; Bean, M.J., eds. 1994. The big kill: declining biodiversity in America's lakes and rivers. Washington, DC: Environmental Defense Fund. 276 p.

Williams, G.P.; Miller, M.G. 1984. Downstream effects of dams on alluvial rivers. U.S. Geol. Surv. Prof. Pap. 1286. [Place of publication unknown]: [Publisher unknown]. 83 p.

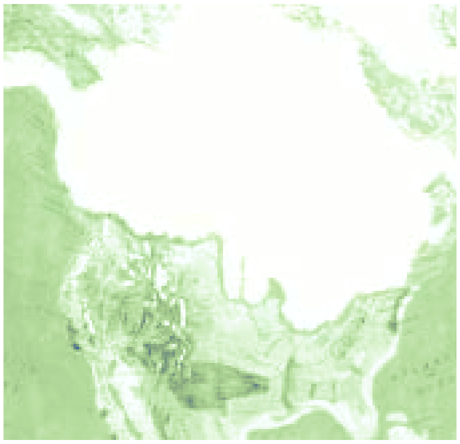
Williams, J.D.; Warren, M.L., Jr.; Cummings, K.S. [and others]. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries. 18(9): 6–22.

Williams, J.E.; Johnson, J.E.; Hendrickson, D.A. [and others]. 1989. Fishes of North America: endangered, threatened, or of special concern. Fisheries. 14: 2–20.

Wilson, Lawrence A. 1995. Land manager's guide to the amphibians and reptiles of the South. Chapel Hill, NC: The Nature Conservancy. 324 p.

Yeager, Bruce L. 1993. Impacts of reservoirs on the aquatic environment of regulated rivers. Norris, TN: The Tennessee Valley Authority—River Basin Operations Water Resources. 112 p.


Photo courtesy Jim Caldwell, Kisatchie National Forest



Chapter 24: Background Paper: Historical Overview of the Southern Forest Landscape and Associated Resources

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Key Findings

- The Wisconsin glaciation of North America peaked around 18,000 years before present (BP) freezing much of the Earth's fresh water in its massive 2-mile thick ice sheet covering nearly 5 million square miles. The forest vegetation was drastically different from our modern forests.
- Climate changed from arid-cool (18,000 years BP) to arid-hot (7,500 to 5,000 years BP) to the current warm-humid climate of the Southeast.
- Humans were well established in the Southeast around 12,000 years BP with fire as their equalizing tool to master the environment. Besides climate, fire was the single most important influence that shaped pre-European forest flora and fauna.
- Climate change, natural disturbance, fire, and humans have constantly affected the vegetative landscape by generating environmental stress or benefit for various species as modern vegetation assemblages developed. These factors contributed to a major extinction of megafauna at the end of the Pleistocene epoch (11,000 to 10,000 years BP).
- American Indian populations in the Southeast were estimated to be 1.5 to 2 million with the development of agriculture. They continued to use fire frequently on a wide scale to clear land and maintain open woods and favorable wildlife habitats.
- The introduction of European diseases had immediate impact on American Indians, causing a population collapse of 90 to 95 percent by 1700. The advent of Europeans and their economic systems impacted American Indian culture and their ability to manage ecosystems by fire, which began a change in composition, structure, and pattern of forest vegetation throughout the Southeast.

Introduction

Had the first descriptions of North America occurred 18,000 years ago, our impression of the vegetation would be very different from that which was recorded 500 years ago by early European explorers. Vegetation 18,000 years ago was radically different than at present (figs. 24.1 and 24.2). How do we know this? The information used to compile the story has many sources. Since no one was around to leave a written record for most of the time, we must depend on science to weave the picture of events over this long period of time. Written historical records began after 1492. Eyewitness descriptions of Amerindians, their culture, the wildlife, and the landscapes they lived on have only been available for 500 years.

Archaeologists have been instrumental in developing knowledge of past human cultures. Their discoveries allow us to see how people lived and interacted with their environments. Paleoecologists have found undisturbed natural ponds, bogs, and other undisturbed wetlands to sample pollen grains deposited over thousands of years. Ecologists and botanists use this information to determine the climatic conditions necessary to support the various species of plants identified from pollen samples. Other ecologists study fire behavior and how fire affects plants and wildlife. Geologists add to our historical understanding by studying landscape and climatic changes related to the movement of glaciers. After the arrival of Europeans, eyewitness descriptions of the landscape and its inhabitants offer a resource rich in information. The combination of all of this professional knowledge is needed to tell this story.

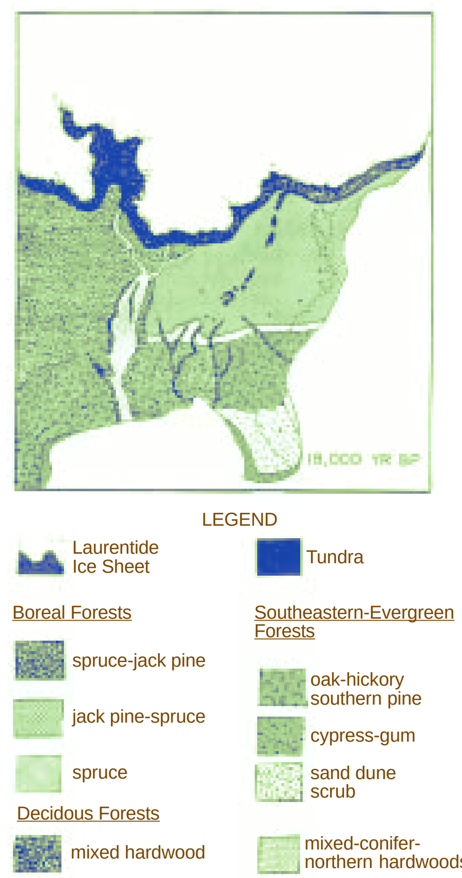


Figure 24.1—Paleovegetation map For 18,000 yr BP (Delcourt and Delcourt 1984).

HISTORY

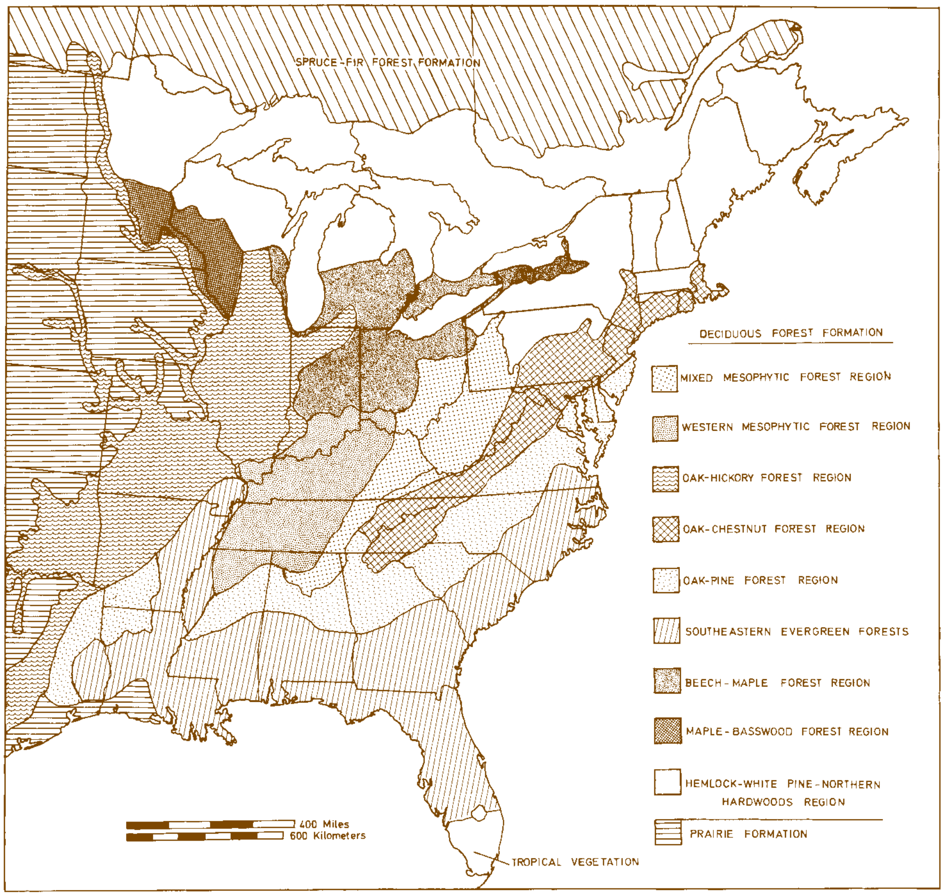


Figure 24.2—Map of potential vegetation types of the Eastern United States (modified from Braun 1950).

The Late Pleistocene Epoch (Ice Age 27,000 to 9,500 Years Before Present)

Research indicates that the late Wisconsin glaciation began to advance about 25 to 27,000 years before present (BP) (Andrews 1987), and that maximum glaciation occurred at 18,000 years BP. Geologists refer to the 2-million year period of Ice Age as the Pleistocene Epoch. During the late glacial period, the Wisconsin, two large ice caps, the Laurentide glacier in the East and Cordellian Glacier in the West, dominated northern North America. Nearly all of Canada lay under the two massive glaciers, which extended into the northern regions of the United States and into the southern one-third of Alaska (fig. 24.3).

These two massive ice sheets were part of an even larger system of ice that dominated the northern hemisphere. Nearly a quarter of the Earth's surface lay under the weight of a mountain of ice. The Laurentide ice sheet is believed to have reached a height of 12,500 feet (Hughes 1987). Ice covered nearly 5 million square miles of North America. As the glaciers grew, they drew more than 50 percent of the Earth's available water, affecting precipitation (Delcourt and Delcourt 1979). The ocean levels dropped, exposing what we call the Continental Shelfs. The expansion of the glaciers dramatically affected the distribution and composition of vegetation.

The leading edge of the glacier in the United States is believed to have been over a mile high (Hughes 1987). Nothing could stand in the way of this massive ice field as it pushed south, grinding over mountains and

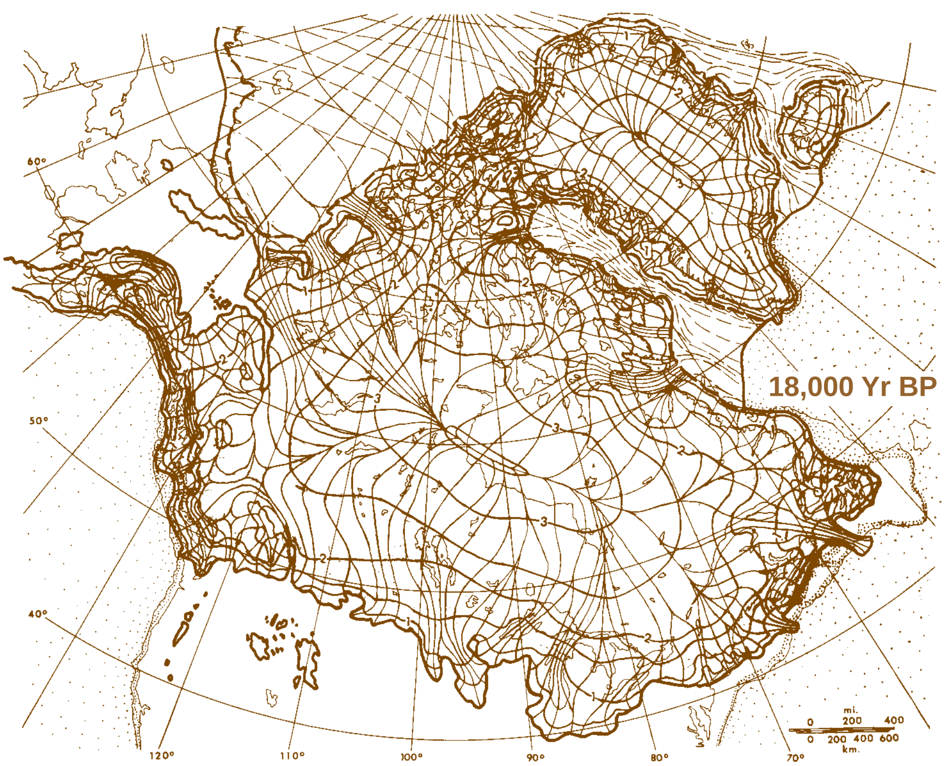


Figure 24.3—The last glacial maximum in North America simulated by a geomorphic model. Ice-elevation contour lines are shown at 0.5-km intervals at 18,000 yr BP. Surface flowlines drawn normal to surface contour lines are solid for grounded ice and dashed for floating ice. Ice-sheet margins are heavy solid lines and ice-shelf grounding lines are heavy broken lines. The edge of the Continental Shelf is taken as the 0.5-km bathymetric contour and is shown as a thin line beyond present-day coastlines. The extent of seawater is the dotted area (Hughes 1987).

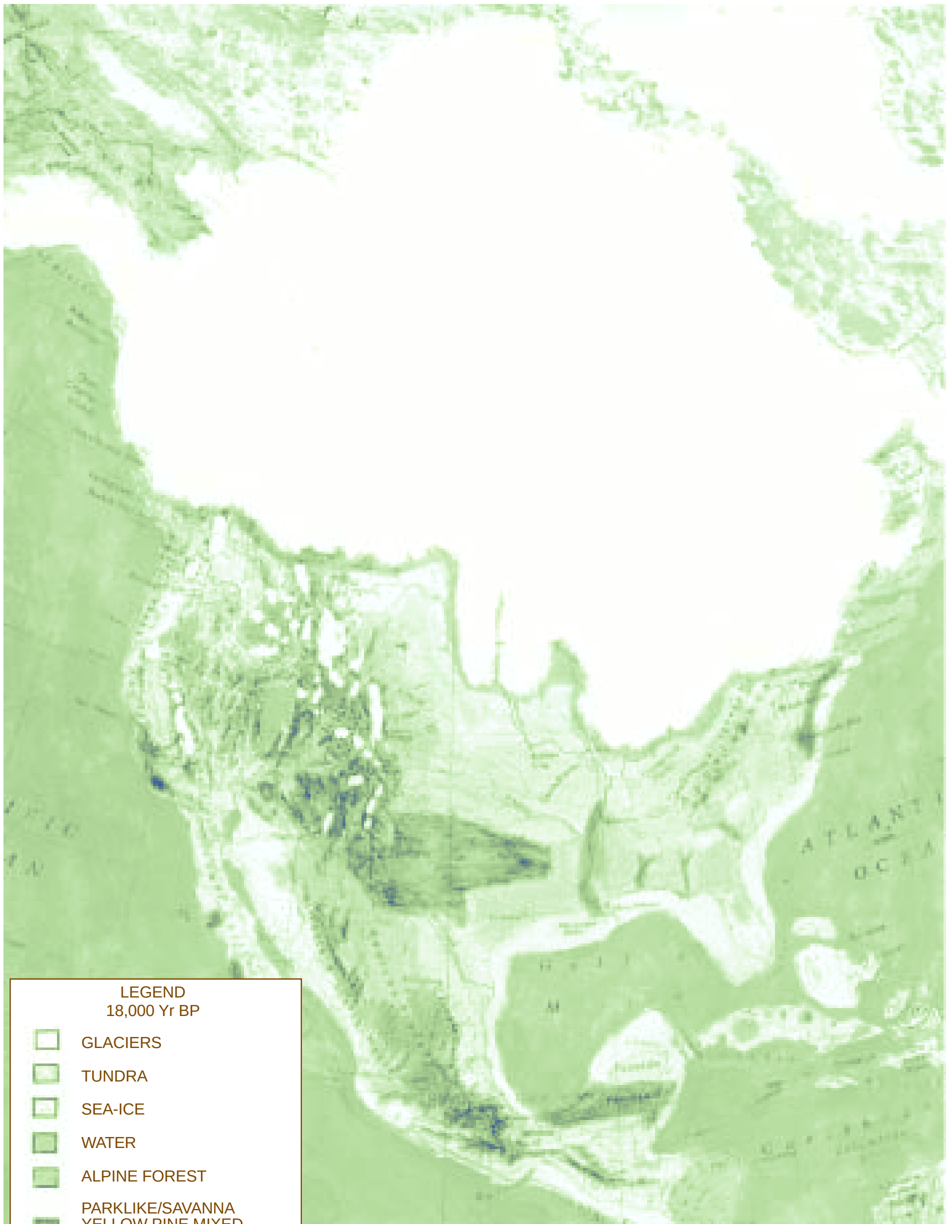


Figure 24.4—Maximum extent of North American glaciers and a generalized concept of vegetation based on less precipitation in most areas (modified from Delcourt and Delcourt 1985, Martin and Mehringer 1965, data from the Center of Climatic Research 2000).

depressing the land under its massive weight. Over the ice caps, a huge high-pressure system pushed the polar jet stream southward, dominating weather patterns over much of the northern hemisphere (Barry 1983, Kutzbach 1987). The ice sheets influenced temperatures far to the south, and both vegetation and wildlife retreated in its front (Graham and Mead 1987, Jacobson and others 1987). The vegetation map (fig. 24.4) depicts the magnitude of the glaciers and the proportion of Earth's water frozen into the 12,000-foot thick ice sheet and graphically illustrates the extent vegetation was influenced by this glacial system.

By 18,000 years BP, boreal species dominated by jack pine and spruce had been pushed as far south as 34° N. latitude, which is near present-day Atlanta, GA. Temperate deciduous tree species dominated by oaks existed just south of the broad boreal region. Temperate forest species extended south onto the exposed Continental Shelf into the Gulf of Mexico (Delcourt and Delcourt 1984, Watts 1980) (fig. 24.1).

Full Glacial Landscape (18,000 Years BP)

Pollen core samples provide clues to tree distribution and composition of the full glacial landscape, but they must be interpreted with caution when making broad statements about the complex characteristics of forest types. Because all pollen cores are taken from mesic sites (wet areas), like bogs, natural ponds, pocosins, etc., mesic species may be overrepresented.

Delcourt and Delcourt (1984) developed a vegetation map for Eastern North America for 18,000 years BP, based on a number of pollen studies scattered throughout North America (fig. 24.1). This map represents the potential distribution of vegetation types in regions of Eastern North America. Delcourts' map shows boreal forest in the Southeast to 34° N. latitude. Jack pine was the dominant species followed by spruce, and oak formed a minor component near the boreal/deciduous interface near 34° N. latitude (Watts 1980). Below 34° N. latitude, oaks were the dominant tree species with hickory as an associate. However, the excessively dry climate of the time affects vegetation assemblages throughout the Southeast (Barry 1983, Delcourt and Delcourt 1979). A potential misinterpretation of the oak-hickory and boreal species assemblage, as depicted, is that it may give the impression of a completely forested landscape.

It is evident from the massive dimensions of the glacial systems and their influence on worldwide precipitation that what is termed forest at 18,000 years BP did not have a closed canopy. Rather, trees were scattered over a dry landscape, occupying sites where moisture and growing conditions were favorable for tree survival and growth (fig. 24.5). And what about the size of individual trees? Under these droughty conditions, many soil types in the South may have supported only scrub trees, or no trees at all. Extensive areas were probably dominated by prairie or sagebrush-dominated areas (Watts 1980) (fig. 24.5). Delcourt and Delcourt (1979) have estimated that current mean annual precipitation may have been reduced by more than half during full glaciation. Reducing present mean annual precipitation for the Southeast by more than 50 percent produces climatic conditions similar to the arid areas of the West today (U.S. Department of Agriculture 1965) (fig. 24.6).

Significant herbaceous pollen (grasses, sagebrush, and smartweed) appears in the profile from White Pond, SC (fig. 24.7). This quantity of herbaceous pollen would not be possible under a closed canopy forest (Watts 1980). Away from this mesic site, on xeric (dry) uplands, drought-tolerant grasses and sagebrush probably dominated the landscape.

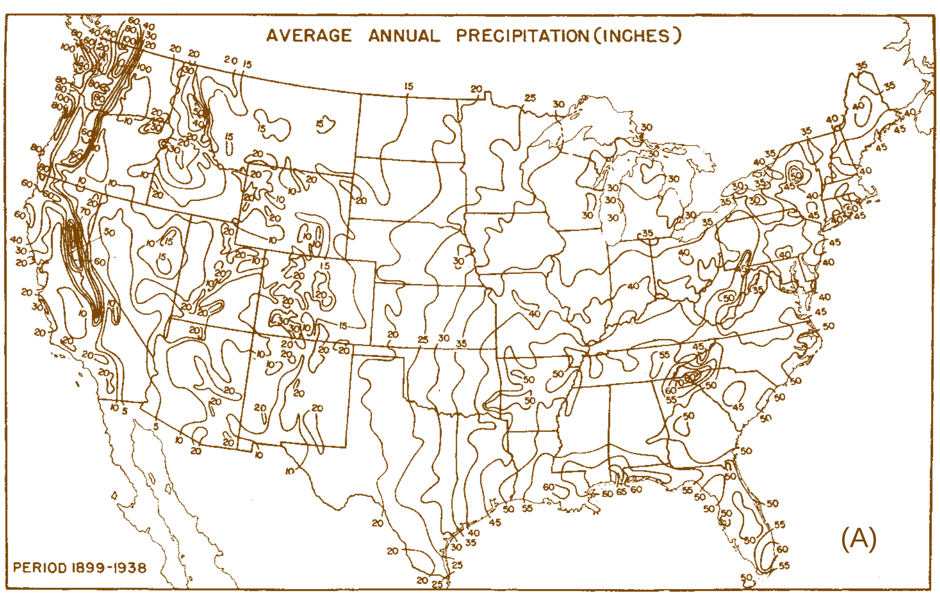
Due to the extremely arid climate, vegetation consisted of trees clumped in favorable locations or scattered over the landscape in open park-like savannas, in association with prairies and scrublands. Organization of the vegetation mosaic was controlled by the moisture gradient from the well-drained uplands to the moist areas of the bottomlands.

Precipitation was also greatly reduced in the now super-humid Appalachian Summit. The arid climate produced a mosaic of grasslands, park-like savannas, and tundra at higher elevations. Dominant tree species were firs and spruces on moister sites with jack pine occupying drier sites (Delcourt and Delcourt 1984, Watts 1983).

South of 34° N. latitude, the deciduous tree assemblage dominated by oaks and hickory was able to survive. The arid climate and variations in soil types also produced a mosaic of park-like savannas with extensive prairies, sagebrush, and scrublands. Large grazing mammals existed throughout the South and required large amounts of herbage to live. Their existence supports the idea of extensive rangeland in the South because that habitat would have been necessary for their survival (Graham and Mead 1987, Guilday 1982, Kurten 1988, Lundelius and others 1983).

As a result of the arid climate and lower ocean levels, rivers and water tables were considerably lower (Edwards and Merrill 1977). Riparian areas, seeps, and springs provided a refuge for moisture-loving trees such as beech. Delcourt and Delcourt (1979) theorize that the eastern escarpment of the Mississippi River and the eroded

Figure 24.5—Dramatically lower mean annual precipitation in the Southeast during the ice age created an arid climate similar to our present Southwestern United States. Trees would have existed only in favorable locations (A) and (B). Extensive areas of droughty soils in the Southeast would have only sustained grasslands, and scrubland landscapes (C).



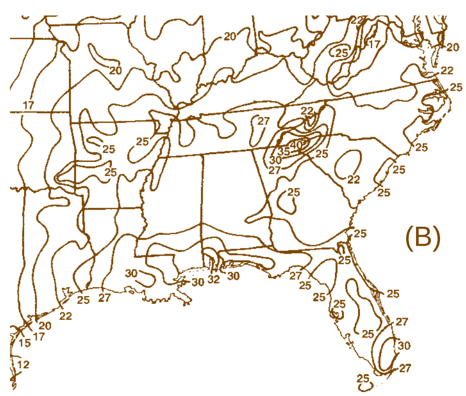


Figure 24.6—Present mean annual precipitation for the United States (A). The mean annual precipitation in inches at 18,000 yr BP is shown in (B). For most of the 2 million years of the ice age the mean annual precipitation was significantly less than today (modified U.S. Department of Agriculture 1941).

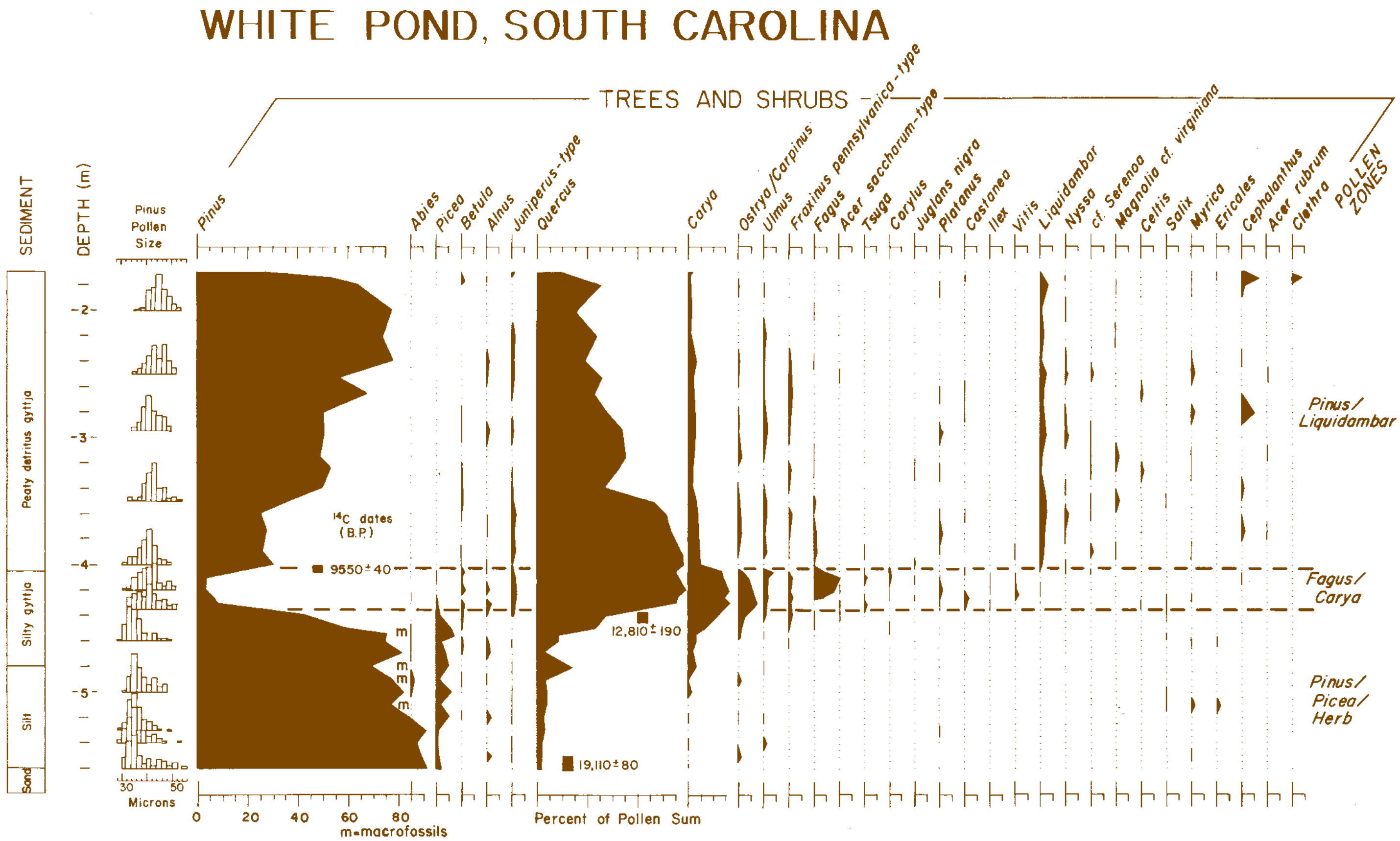
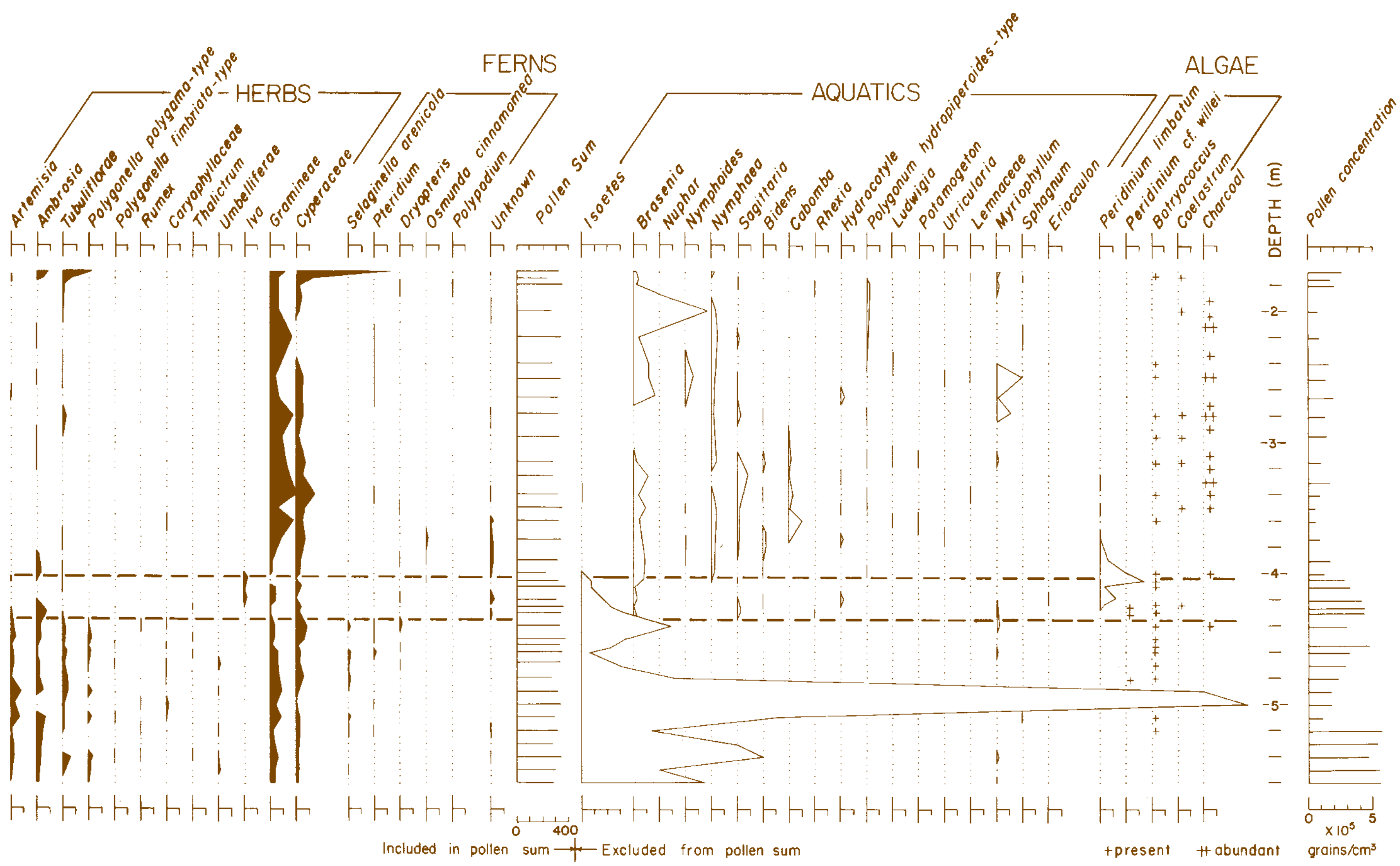


Figure 24.7—Pollen profile from White Pond, SC; an early pollen profile study. Other southeastern sites have added knowledge of vegetation composition during the past 18,000 years (Watts 1980).



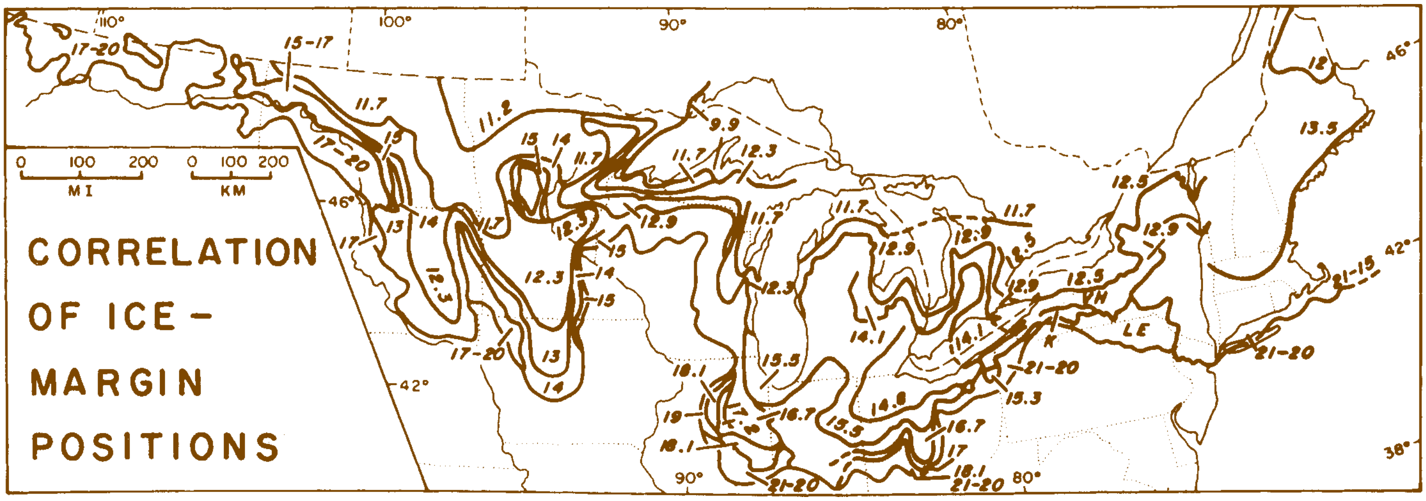


Figure 24.8—Late glacial record of the Laurentide Ice Sheet. Tentative correlation of ice-margin positions or readvance limits. Areas where no ice-front positions are shown are poorly known. Ages are in thousands of years before present (Mickelson and others 1983).

gorges where streams entered the river provided refuge for many tree species during full and late glaciation. They also suggest these landscape features provided important migratory routes for tree species during changing climates.

Beaver may have been important during this period for creating inundated wetlands that supported shrubs and mesic herbaceous plants. These wet habitats probably attracted many species of wildlife, as well as waterfowl displaced by the glaciers.

Ocean levels are believed to have been 400 feet lower than at present. The exposed Continental Shelf extended from 60 to 90 miles beyond the present shoreline (Edwards and Merrill 1977, Jacobson and others 1987) and is believed to have harbored northern hardwoods in the vicinity of the Carolinas. This exposed and relatively flat land would have contained bogs and swamps interrupted with scrublands dominated by deciduous species along with southern pine.

Ice Age Wildlife

The vegetation provided habitat for many wildlife species that are either extinct or extirpated from the region today. Fossil evidence for full-glacial fauna in the Southeast is scarce because the highly humid climate and soil types deteriorate fossils. However, in areas where limestone is found, such as Florida, Tennessee, Kentucky, West Virginia, parts of the Coastal Plain, and in natural bogs, some fossils have been preserved. These fossils provide evidence of diverse wildlife species that existed during the Ice Age (Guilday 1982). The abundance of wildlife may have been partially due to a more moderate climate created by the large glaciers, without the extremes of our more continental weather today (Kurten 1988).

The glacier squeezed boreal, temperate, and subtropical ecosystems into a smaller land area. Wildlife species adapted to boreal conditions could easily migrate seasonally to forage in neighboring temperate or even subtropical ecosystems.

Webb (1981) reports the presence of wooly mammoths as far south as Charleston, SC, where fossil records indicate that tapirs and capybaras were also found (Kurten 1988, Webb 1981). Fossil records of the boreal region during full glaciation include wooly mammoths, horses, caribou, bison, moose, black bears, beaver, and several species of musk oxen, among many other species.

Temperate region fossils include browsers such as mastodons, elk, white-tailed deer, sloths, peccaries, and grazers such as Columbian mammoths, bison, horses, llamas, along with black bears, beaver, spectacled bears, and a host of other species.

The subtropical region included many of the same species found in the temperate and boreal regions plus tapirs, capybaras, and alligators. Guilday (1982) reported that mammal diversity during this time consisted of at least 75 species. This number is 32 percent greater than mammals represented when Europeans arrived. In addition, 26 mammal species at full glaciation were large, compared to 6 large species in 1500.

The diversity of grazers and browsers supports the hypothesis of great ecological diversity. The landscape of scattered copse and individual trees mixed with grasslands formed numerous vegetation edges (ecotones) no longer present in the South (Guilday 1982, Webb 1981).

Changing Glacial Climate (16,500 to 9,500 Years BP)

Pollen samples from the Eastern United States indicate vegetation changes in response to a glacial retreat around 16,500 years BP (Delcourt and Delcourt 1984). The retreat was not constant but was interrupted by at least six or seven advances, each lasting 700 years. However, no advance reached the glacial maximum of 18,000 years BP (fig. 24.8). A number of physical changes in the glaciers were associated with the glacial retreat. By 12,500 years BP, the extent of the Laurentide glacier had slightly diminished, but the height of the dome had decreased by more than half to 5,900 feet (fig. 24.9) (Hughes 1987). The glaciers now contained 25 percent of the Earth's water available for precipitation (Kutzbach 1987).

Although somewhat less massive, the glacier continued to dominate

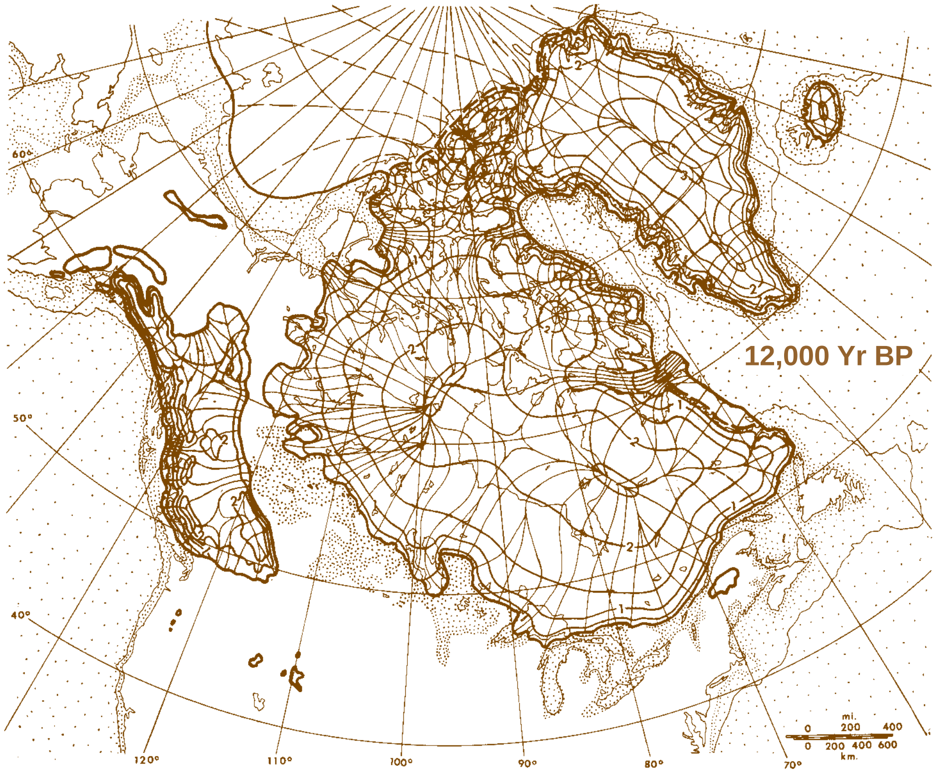


Figure 24.9—The glacial sheets of North America at 12,000 yr BP (Hughes 1987).

the climate of the United States, and especially land east of the Mississippi River. A significant ice cap still covered most of Canada (Hughes 1987) (fig. 24.9). After 16,500 years BP, the glacial retreat was occasionally interrupted by readvances brought on by temperature fluctuations. Readvances were within 100 to 200 miles north of the maximum extent of 18,000 years BP. This occurred at least three times during the late glacial phase—at 12,900, 11,700, and 9,900 years BP (Edwards and Merrill 1977, Mickelson and others 1983) (fig. 24.8). Logically, the increased presence of ice during readvances came at the expense of precipitation over the continent.

Precipitation models indicate that current precipitation averages were not attained in the Southeast until after 9,500 years BP (Kutzbach 1987). Webb and others (1987) also reported that annual precipitation in the Southeast remained below present levels. Barry (1987) states that temperature and precipitation rose in the Southeast between 12,800 to 10,000 years BP but remained below modern averages. Kutzbach (1987) reported lower sea-surface temperatures in the western Atlantic, which contributed to reduced summer temperatures in the Southeast. Summers were droughty, which controlled vegetation composition and distribution. This information supports a drier climate as opposed to a climate with abundant precipitation as indicated by Delcourt and Delcourt (1984).

The retreat of the glacier was accompanied by a rise in ocean levels. By 12,000 years BP, the ocean rose to within 30 to 60 miles of the present shoreline. The rising ocean, accompanied by an increase in mean annual precipitation, lifted coastal river levels, increased streamflow, and raised water tables. However, both sea level and precipitation remained lower than at present (Edwards and Merrill 1977).

Late Glacial Vegetation (12,500 to 9,500 Years BP)

The glacial retreat strongly affected vegetation distribution and composition. Tree species began migrating inland away from encroaching ocean waters, as well as northward due to climatic warming. Mesic species took advantage of the increased moisture in riverine watersheds. Since the Laurentide glacial dome continued to cover eastern and middle Canada, the direction of most of the retreat was from west to east. The remaining large ice dome in the east prolonged the glacial climate along the eastern seaboard. The earlier warming in the western South explains the early development of a spruce and oak assemblage prior to 12,500 years BP in the Ozark Highlands. The prolonged cooler climate in the East maintained the presence of spruce in Virginia as late as 10,000 years BP or later (Wright 1987).

As the glacier waxed and waned between 16,500 to 12,500 years BP, vegetation dynamics were intense. Edwards and Merrill (1977) described this period as "ecologically restive." The assemblage of tree and plant species had no modern analogue (Davis 1983). Boreal vegetation and tundra moved into newly opened land in the northern regions abandoned by the massive ice fields. Boreal forest in the Eastern United States by 12,500 to 11,000 years BP ranged south in a broad band into Virginia and Kentucky (37° latitude) and farther south, narrowing along the Appalachians summit into North Carolina and Tennessee. Here, residual boreal species exist today at high elevation.

Deciduous trees, especially oak, dominated the taxa over much of the South. Mesic hardwoods, such as ironwood, beech, and maples, were important along river systems and wet areas. Watts (1980) research at White Pond in South Carolina indicated the presence of a deciduous forest dominated by oaks at 12,800 years BP. The oaks associated with hickory and beech made up as much as 55 percent of the nearby tree species; some ironwood and hornbeam were present (fig. 24.7). He concludes that the climate was cooler and moister than today, implying that the forest was "mesic", but he urged caution in using this term.

Delcourt and Delcourt (1984) also refer to climate at this period as "cool-temperate" supporting mesic forests. They theorize that abundant moisture was available during the growing season in the mid-latitudes of the Southeast north of the 34° N. latitude. However, there is reliable information to suggest that between 12,500 to 10,000 years BP the climate of the Southeast was cooler but drier, rather than moister than at present. During the late glacial period the ocean level was still 100 to 130 feet lower than at present, and river levels and water tables were correspondingly lower. Lower precipitation, particularly during the summer growing season, would have had profound effects on vegetation (Kutzbach 1987).

Watts (1980) and Delcourt and Delcourt (1984) proposed a mesophytic forest during the late glacial period north of the 34° latitude. However the mesic hickory-beech association composed only 25 percent of the pollen at that time (fig. 24.7). The dominant pollen at White Pond, SC, for the period 12,800 to 10,000 years BP was the shade intolerant, ring-porous, drought resistant oak. Hickory, which comprised 15 percent of the pollen profile, is also ring porous and should be considered part of the oak assemblage. Oak, therefore, was the dominant forest type at the time. It dominated the upland areas. Mesic species, such as beech, ironwood, hornbeam, elm, ash, and maple, were assigned to the waterways or moist areas such as White Pond. Therefore, the pollen evidence from White Pond supports a dry climate rather than a moist climate.

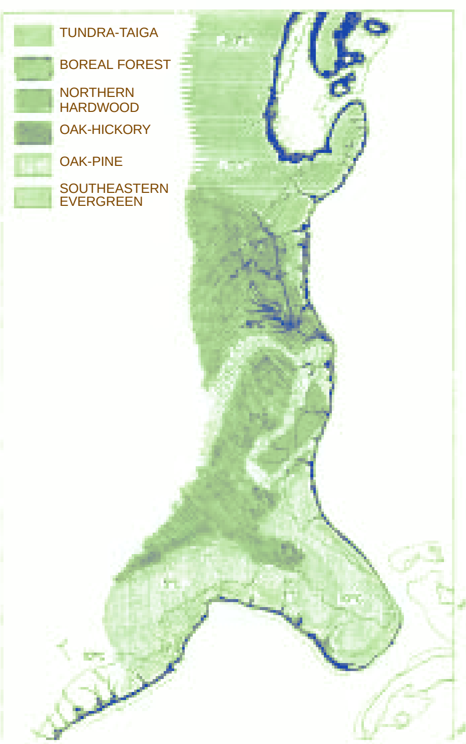


Figure 24.10—Forest types for 12,000 yr BP along the eastern seaboard with average temperatures for this period. The climate is relatively dry and terrestrial vegetation that needs moisture is found near rivers and other moist sites. Oak and hickory dominate most uplands of the Southeast. Boreal species inhabit the mountains, while southern pine is a multiplying component of the southeastern Coastal Plain (modified Edwards and Merrill 1977).

The map by Edwards and Merrill (1977) (fig. 24.10) represents a plausible model for dominant tree taxa at 12,500 years BP for the Atlantic Seaboard, based on a drier climate. Jacobson (1987) also supports a dry climate by indicating that the oak-hickory forest was dominant over the entire Southeast at this time. Oaks and hickories produce leaves rapidly in the spring when soil moisture is highest from winter recharge and transpiration is low, and they have the ability to produce and store energy at leaf flush. If droughty weather occurs later in the growing season, they shut down their systems and wait for sufficient soil moisture. They are shade-intolerant species and need repeated disturbance to maintain quality regeneration on all sites (Brose and Van Lear 1998). Without disturbance in high precipitation regions, oaks and hickories have difficulty competing with diffuse-porous mesic species and lose their dominance in the stand or disappear altogether.

Late Glacial Landscapes—Mesic Or Xeric?

Soil types, drainage, and aspect strongly influence vegetation composition and distribution. In the Southeast, the Piedmont, Sandhills, and Highland Rim consist of rolling uplands, ridges, and hills. Sandy Coastal Plain soils are well drained. These landscapes were dissected by riverine drainages. Even with current levels of precipitation, upland and deep sandy soils are well drained or excessively drained and droughty.

Since it has been established that the climate at 12,500 to 9,500 years BP was more arid than today, the landscape would have supported fewer and smaller trees. The lack of precipitation during the summer growing season (Kutzbach 1987) would drastically reduce tree growth. Only the hardiest trees would survive, and the droughty conditions would enhance the frequency of fire. On droughty sites, grasses would be favored because they are more drought and fire tolerant. The harsh conditions resulted in widely spaced trees in park-like savannas, enhancing both browsing and grazing potential for wildlife. In many areas, only scrubby forms of oak and pine could survive extended drought.

In Florida during the late glacial period, the water table was 50 feet lower than today (Watts 1971). Throughout the Southeast, forests along the rivers were probably open, with rich herbaceous plant communities on river terraces. This condition may explain the increased presence of ironwood and hornbeam pollens in core samples during this period. Further support for open forests was reported by Jacobson and others (1987), who said, "the widespread appearance of ironwood, in particular, supports the notion that a broad woodland of open-grown vegetation existed south of the ice sheet; this tree flowers and produces abundant pollen only when growing in well lighted conditions." Davis (1983) indicated that the abundance of ironwood pollen in early Holocene sites in New England is compatible with a drier climate and a higher fire frequency. Ironwood today is characteristic of woodlands in Minnesota, growing along the prairie margin where fires are frequent. Delcourt and others (1999) also postulated a climate that promoted frequent fires favored taxa such as ironwood and hornbeam. They also noted that disturbances would have created patchy sunlit spots for the weedy growth of ironwood and hornbeam in shrubby thickets near mesic sites.

Ironwood and hornbeam made up less than 10 percent of the pollen profiles at mesic sites north of the 34° N. latitude where the cool temperate mesic forest was proposed (Davis 1983, Delcourt and Delcourt 1984, Watts 1980). Considering all the evidence, it appears that ironwood and hornbeam were growing in open conditions rather than in a closed canopy forest.

Advent of Humans (12,000 to 9,500 Years BP)

In 1926 near Folsom, NM, a cowboy made a fundamental discovery that changed the thinking about the antiquity of humans in the Americas. He discovered the skeleton of an extinct form of bison (*Bison occidentalis*) lying in an arroyo. What was remarkable about the skeleton was that it had a stone spear point located in its rib cage. This was the first reported discovery of human association with extinct Ice Age animals. This spear point style was named Folsom and believed to be at least 10,000 years old. The creation of a new point on the time line for human arrival in the Americas generated much excitement. Previously, professionals placed the earliest humans in the Americas between 4,000 and 5,000 years ago (Fagan 1987).

In 1936 near Clovis, NM, a new and different spear point was discovered in association with the remains of an extinct mammoth, as was another found in 1959 at Lehner, AZ. These spear points were named Clovis. Clovis points were found in stratified soil layers below the Folsom points and radiocarbon dated at 11,340 years BP (Fagan 1987). This discovery established the Clovis culture as the earliest undisputed culture in the Americas.

It is important to understand that the arrival of humans in the Americas had significant impacts on vegetation and wildlife distribution, diversity, and abundance. Since the dates for humans in Eurasia and Africa precede those for the Americas, it is believed that they migrated from Eurasia to the Americas. Originally, it was widely believed that people of the Clovis culture emigrated from Siberia to the Americas via a land bridge. Glaciation lowered ocean levels exposing submerged land, creating a land bridge between Eurasia and the Americas (fig. 24.4). As the glaciers slowly retreated, an ice-free corridor was created in western Canada sometime after 13,000 years BP that could have allowed the first humans to penetrate the Americas (fig. 24.9). Recently it has been determined that this ice-free corridor was probably uninhabitable during this period, due to extremely harsh conditions. Additionally, archaeologists have not found any evidence of the Clovis culture at the time the ice-free corridor existed.

There are possibly some sites of early human habitation in both the Americas that predate the Clovis period, which has led to the speculation of a pre-Clovis culture. New theories have evolved from these speculations. The first Americans could have skirted the glaciers before 12,000 years BP by migrating along the northwest Pacific coast in small boats as they either fished or hunted marine animals. A more recent theory suggests an Atlantic Ocean route from Europe. This theory is based on lithic similarities of spear points between Clovis and those of the European culture (Anderson and Faught 1998, Parfit 2000, Roosevelt 2000).

The discovery of Clovis points in association with extinct megafauna labeled Clovis people as big-game hunters. A widespread romantized view developed of fur-clad people in pursuit of or in direct confrontation with the massive mastodon, mammoth, or giant bison. These images have changed little in the decades since the discovery of Clovis points. However, increasing archaeological evidence implies a more complex existence for these people, which is more in keeping with the complexity of human beings in general.

These early Americans, like most hunter-gatherers, were opportunists. Evidence clearly indicates they hunted the now extinct megafauna; but they also hunted many other animals, such as deer, elk, caribou, peccaries, and smaller animals like rabbits. They also took fish and gathered wild plants (Anderson and Faught 1998).

Some archaeologists have dismissed extinct megafauna hunting in the East. They believe only extant wildlife such as deer, elk, or caribou were taken. Other archaeologists believe that the Clovis culture may have developed in the Southeast (Anderson and Faught 1998). The highly complex personal stone tool kits of the southeastern and eastern Clovis people were as well developed and of identical size as those of their western Clovis cousins (Anderson and Faught 1998, Cotter 1991, Dragoo 1976, Fagan 1987). This similarity suggests that the Clovis people in the Southeast were hunting similar species of wildlife as their western cousins during the same period. Increasing archaeological association of Clovis culture with extinct fauna in the Southeast confirms this belief (Anderson and Faught 1998).

One reason for the confusion about species hunted by the Clovis culture is the belief that the vegetation of the Southeast between 12,500 to 9,500 BP was closed-canopy mesic forest with abundant rainfall during the growing season (Delcourt and Delcourt 1984). A more plausible description of the southeastern landscape is that it was an open park-like mosaic of scrubland, prairies, and savannas (Edwards and Merrill 1977). This type of habitat is required by megafauna, which indisputably lived in the Southeast. The arid climate of the late glacial period produced extensive megafauna habitat, especially on well-drained droughty soils of the Piedmont, the Sandhills, the Highland Rim, and sandy Coastal Plain soils. Some of the largest concentrations of Clovis artifacts are found in the Southeast in immediate association with these droughty areas (Anderson 1991).

Clovis hunters (12,000 to 10,500 years BP) and later Paleo-Amerindians (10,500 to 9,500 years BP) were hunter-gatherers who traveled in small mobile bands of loosely related kinsmen and functioned as a social unit for economic purposes. These small bands of about 40 people covered extensive territories in their "seasonal rounds" of food procurement. Seasonal movements were structured to optimize the procurement of food (Blanton and Sassaman 1989, Hudson 1976).

During the fall, several related bands would join for ceremonial activities and hunting. The synergistic effort of the larger unit procured large quantities of meat to be dried for winter consumption. As the fall season progressed and game dispersed due to hunting pressure, the bands also dispersed to more favorable hunting areas until the arrival of spring (Hudson 1976, Walthall 1980).

In the spring, activities included gathering of plants, fishing, and collecting shellfish (fresh water mussels). Hunting, fishing, and plant gathering continued throughout the summer.

Human Ecology

The techniques for procuring food had been learned over thousands of years. Wing and Brown (1979) observed, "Not only must people eat regularly, but the cost in terms of energy expenditure of obtaining and using food cannot be greater than the energy derived from these foods." Associated with this cost is another factor . . . risk. Examples of regions that are high risk for human survival are deserts or arctic regions. Risk is also involved with the species hunted (Champion and others 1984). Since

Clovis people sometimes hunted animals, such as mastodon or mammoth, the risk versus the benefits of confronting such colossal animals had to be calculated. A direct confrontation was life threatening, but the potential benefits were enormous. Hunter-gatherers needed an economical and efficient food-gathering strategy. A group must minimize cost and risk, and maximize food quantity and predictability. Innovative hunting and gathering techniques sought an optimized time, place, and harvest quantity. An annual cycle, called the "seasonal round", was designed around seasonal changes in plant abundance and wildlife behavior (Champion and others 1984, Hudson 1976, Lee and DeVore 1968).

These successful techniques can be observed today in extremely high-risk areas such as the Kalahari Desert of Africa. In only 2 1/2 days, adult Bushmen procure food resources that exceed energy requirements for 1 week (Lee and DeVore 1968).

Cowdrey (1983) states that the "southeastern natives could live off the landscape's natural resources, using manual labor for only about one-fourth of the year's subsistence." The reported acumen of hunter-gatherers rules out any thought of their wandering aimlessly across the landscape in search of the next meal.

Humans are the only creatures on Earth that for thousands of years have reasoned, organized, and carried out plans for their survival in almost every climate on Earth. Without this ability, people would not have populated the Earth but would have remained isolated in some benign niche or even become extinct. Humans have never been mere observers of nature; they have always employed their observations to directly manipulate the environment for their benefit. This process evolved beyond mere survival but enhanced abundance for a better quality life.

Natural climatic disturbances, including fire, created diversity in the ecosystems. The disturbed areas favored many plants and trees that produced berries, nuts, or forage. Since fire was the one natural tool that could be controlled, it became the agent for modifying the landscape. Humans could now mimic natural disturbances over a large territory to enhance plant and wildlife populations for hunting and gathering.

Managed Human Ecosystems

There is growing scientific evidence that at a very early period humans manipulated vegetation to attract game and improve food-gathering possibilities. In Europe as early as the Acheulian Period (250,000 years BP) and later during the upper Paleolithic Period (80,000 to 25,000 years BP), fire was used to drive game and enhance vegetation quality. Some forests were deliberately cleared as indicated by pollen analysis from various locations in England. An open forest with scattered trees and clearings produced fresh enriched and palatable sprouts attractive to many wildlife species (Champion and others 1984, Kurten 1972). These open forests favored plants that require more sunlight, such as species that produce fruit. These plants were likely to be trees that produce nuts (oaks) or plants that produce soft fruit such as raspberry. The open forests not only attracted wildlife that could be eaten but provided vegetation for direct consumption. Pollen analysis in Denmark indicates that closed-canopy forests prevailed there around 12,000 years BP, creating survival problems for humans. In response, they reduced the forest overstory with fire. In turn, this disturbance led to increases in human settlements (Champion and others 1984, Kurten 1972).

Migratory patterns of large herbivores can cover large areas and be unpredictable. The occurrence of more diverse and abundant plant resources, results in a greater diversity and abundance of wildlife species (Champion and others 1984). The manipulation of vegetation by prehistoric humans can be viewed as structured hunting. Herds were attracted to locations by improving foraging opportunities. According to Champion and others (1984), this manipulation of wildlife blurs the distinction between hunting and other forms of exploitation and may be considered semi-domestication (Hudson 1976). Perhaps these techniques were the foundations of animal domestication.

Similar manipulation was applied in the Southeast (Hudson 1976). The descendants of Eurasian people brought the ancient tool that could change landscapes: fire!

Prehistoric Fire

Fire has had a long relationship with humans. It is not known when we first tamed fire, but it was very long ago. The folklore of many cultures contains stories of taming fire. Generally, the arrival of fire in these cultures is related to stealing fire or receiving it as a gift from a Supreme Creator (Hoebel 1972, Hudson 1976). Southeastern tribes believed that fire was the earthly representative of the sun. Fire was from the Upper World and was so sacred that it was reverently addressed before any ceremonial proceeding and never polluted with water, which was from the Lower World. In August at the beginning of a new year, all fire was extinguished and rekindled anew. High Priests warned that those people who failed to extinguish their fires properly would be punished by the divine fire (Hudson 1976).

Fire performed many functions for southeastern Indians. Corrective fires were used to open up the older stagnated timber stands to enhance food production (Bonnichsen and others 1987, De Vorsey 1971). Fire was used to control pests such as ticks and mosquitoes. Even the smoke, which was an integral part of the sacred fire, was believed to purify the air for breathing by eliminating lurking diseases (De Vorsey 1971).

Fire provided safety from predators because of their natural fear of fire. Fire offered warmth and light and created a sense of security. It cooked food, and it dried meat and fruit for later use.

Humans penetrated remote and unpopulated areas of Europe, Asia, and finally the Americas by following a retreating glacier. Surviving the cold and brutal climate was only possible because of fire. "Fire could have made the difference between survival and extinction in the regions occupied by human beings" (Coon 1954).

Fire was an equalizer, allowing humans to drive game and confront prey and predator. Fire was the commanding tool that not only allowed humans to survive, but also provided a margin of comfort. It gave humans greater mastery of their environment, and it was around campfires that the first seeds of civilization were planted.

Late Paleoindians (10,500 to 9,500 Years BP)

Evidence places the demise of the Clovis culture at about 10,700 to 10,500 years BP (Blanton and Sassaman 1989). This change may have been due to climatic changes, which affected hunting strategies. Even during the Clovis period some changes in spear point style were noted in some southeastern locales, such as Cumberland and Suwanee. These changes in technology were slight and continued to reflect Clovis culture.

However, by 10,500 years BP, a shift in spear point size is apparent in Quad and Simpson points. This size reduction may be attributable to changing subsistence activities (Milanovich and Fairbanks 1980, Walthall 1980). By about 10,000 years BP, a number of new spear point styles were being made. Hardaway and Dalton spear points, considered transitional technology from the Paleo to Archaic Period, represent a possible shift toward smaller territorial exploitation and an increasing reliance on hunting more modern game species, such as deer, elk, bison, turkeys, and squirrels (Coe 1952, Goodyear 1982, Goodyear and others 1979, Walthall 1980). These are the same species that continued to be hunted by southeastern Indians until Europeans arrived. Also, there seems to have been an increase in gathering of foods, such as hickory nuts, walnuts, acorns, and fruits, suggesting a changing culture and possibly more defined territories (Goodyear 1982, Walthall 1980).

The patterns for seasonal rounds in the Southeast were being established during this period. In the fall, hunters and their families moved to favorable hunting grounds to hunt deer and gather nuts and late-season fruits for winter. At these locations, fire was used to drive game and clear out brushy areas to enhance spring fruiting plants, as well as to encourage more palatable forage for wildlife.

Burning the underbrush also reduced concealment of large predators that could threaten lives, especially of children. Such burning was a defensive measure and in later times would apply not only to predatory animals, but also to human predators. In areas where nut-bearing trees grew, burning the leaves and underbrush exposed the nuts, allowing quicker and more complete gathering. Humans thereby increased their chances for success in competing with animals for this valuable food. These methods continued to be used by southeastern Indians thousands of years later (Catseby 1974, Hudson 1976, Mooney 1900, Walthall 1980).

Changes in climate and vegetation altered wildlife habitats and perhaps caused rarity or extinction of big game like mammoths, horses, and mastodons. In some areas, southeastern Indians began shifting their hunting activities toward animals that remained in the Southeast. The extinction or rarity of big game species appears evident by 10,000 years BP (Graham and Mead 1987, Hester 1960, Martin 1967). The disappearance or dispersion of many species that had existed in Southeastern North America coincides with the end of the Pleistocene (Pielou 1991).

Archaeological evidence indicates that at a very early period, white-tailed deer became the most hunted game species, providing the bulk of the native's protein (Hudson 1976). Even though elk, bison, turkey, and a host of small mammals were taken when available, deer became the target species for management. The reproductive rate of deer was better than that of most other large animals left in the Southeast at the end of the Ice Age. The favorable response of white-tailed deer to a changing ecosystem during the glacial retreat surely did not go unnoticed. As a result, it did not take long for the natives to develop exploitive strategies to take large numbers of deer. Deer populations are not self-regulated. Instead, their numbers rise and fall sharply with fluctuations in their food supply, a key factor recognized by the natives in gaining control over their hunting environment (Hartley 1977).

Other than during the rutting season, it is difficult to approach deer. Bucks are distracted and relax their usual defenses during rut, which occurs in the Southeast from late September through November. Also in the fall, deer are attracted to oak forests to feed on acorns; the natives surely recognized that deer reached their optimal weight at this time (Hudson 1976).

If mesic climax forest with sparse herbaceous understory had dominated the landscape, as has been suggested by some, the low browse potential would have supported only sparse and scattered deer populations. Oaks would have been less abundant, which would have reduced a major food source for deer and other game. Since both deer and oaks were important in the native's diet, it was beneficial to enhance the environment for these species and produce predictable environments.

Fire also created prime habitat for turkeys because of increased insect availability and plants that produce soft fruit or acorns. An interspersion of grassy, permanent forest openings in relatively open forest increases turkey populations (Blackburn and others 1975, Davis 1976). In addition, bear, elk, bison, and a host of smaller mammals benefited from fire regimes that increased oaks and produced an open landscape bearing nuts, fruits, and berries (Bendell 1974). The result of this vegetation manipulation by humans created habitat that was conducive to large deer herds. Thousands of years later, Europeans noted the large deer herds. Historical records indicate that deer herds contained as many as 200 animals—a stark contrast to present herds.

The 2,000 years of American Indian burning during the Clovis and Late Paleo Period developed vegetative patterns that would dominate the Southeast for the next 10,000 years. Thousands of years of burning created a landscape that was conducive to frequent, low-intensity fires. These burning regimes produced a mosaic of open forest with savannas, prairies, and a great abundance of herbaceous vegetation and increased the vigor of the ecosystem by releasing nutrients from vegetation to be recycled through the ecosystem (Barden 1997, Bonnichsen and others 1987, De Vorsey 1971, Lefler 1967, Rostlund 1957).

The Holocene Epoch (10,000 Years BP To Present)

Although the glaciers would not totally disappear for another 3,500 years, the year 10,000 BP ended the Pleistocene Epoch, or Ice Age. It is believed the Pleistocene Epoch lasted approximately 2 million years with four major glacial periods. The last glacial period, the Wisconsin, lasted

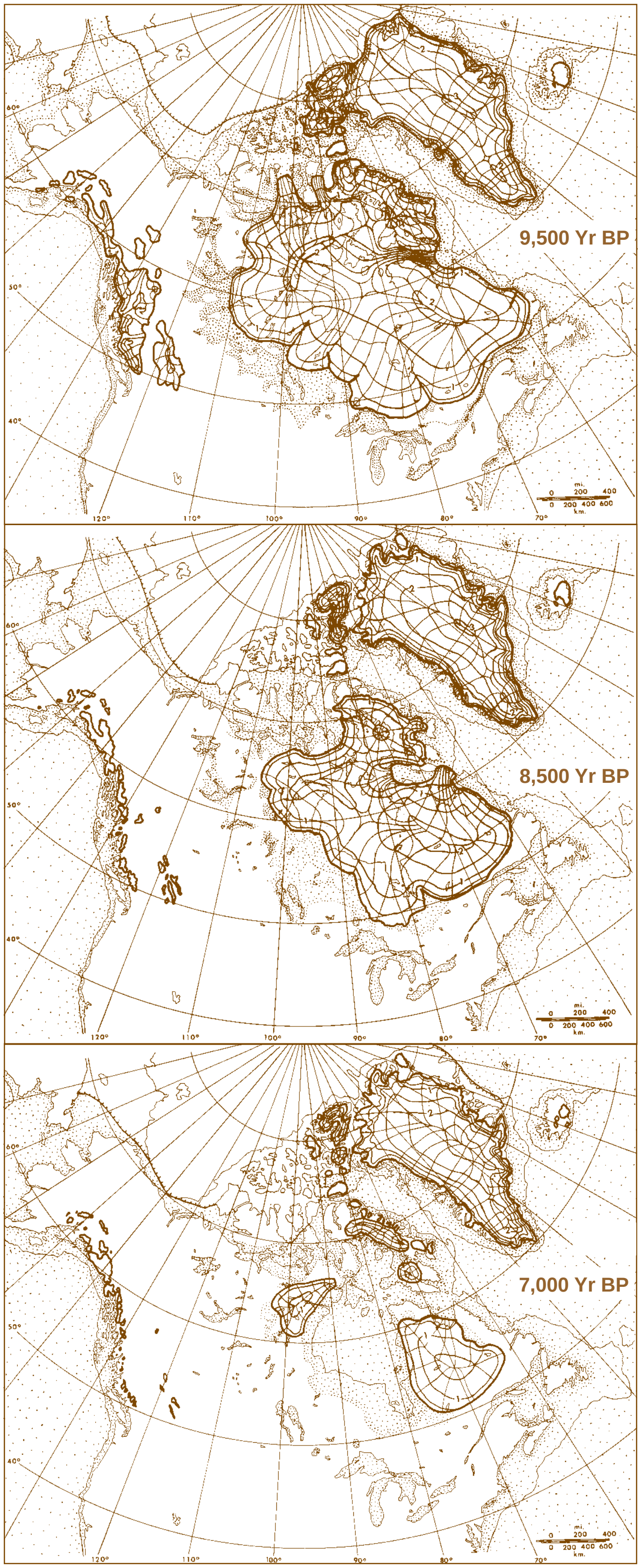


Figure 24.11—Demise of glaciers 9,500 to 7,000 yr BP (Hughes 1987).

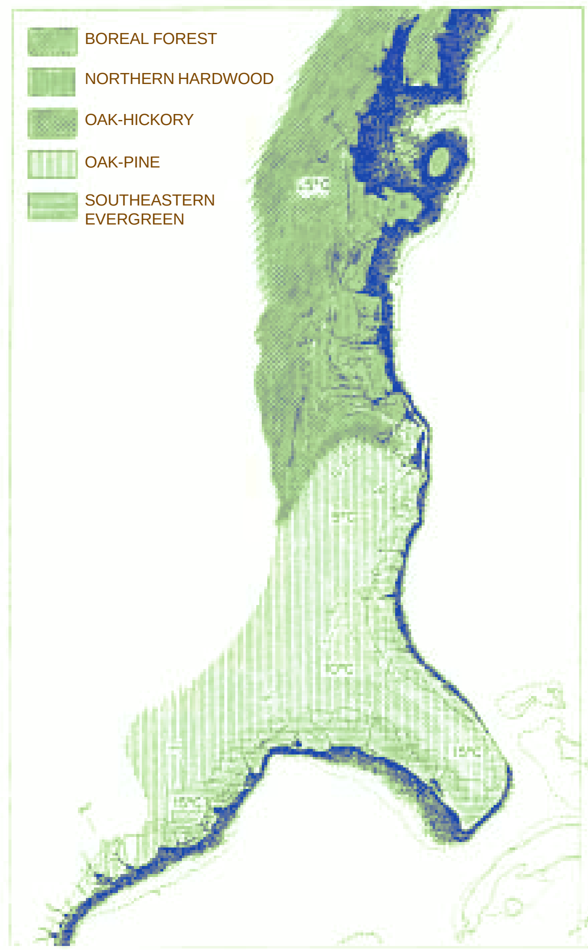


Figure 24.12—Forest types for 9,500 yr BP. Temperatures have risen and precipitation increased due to glacial retreat. However, sea level, river systems, and water tables are still low. Forest species remain south of modern assemblages, and the continuing dry climate produces open forests, evinced by the oak, southern pines, and hickory, which dominate most of the Southeast. Southern pine dispersion and proliferation is attributed to climatic disturbances, arid climate, and natural and native fires (modified Edwards and Merrill 1977).

approximately 100,000 years. The new geologic period, the Holocene Epoch, is an interglacial period and continues today. We are over halfway through our interglacial period that began about 10,000 years ago (Pielou 1991).

An accelerated warming trend began around 9,500 years BP and reached maximum temperatures between 7,500 to 5,000 years BP. Temperatures during this period were warmer than at any time since (Pielou 1991). Higher temperatures melted the remnants of the glaciers in Canada, and the massive ice sheet east of Hudson Bay disappeared around 6,500 years BP (Hughes 1987) (fig. 24.11).

Due to the west-to-east retreat of the glacier, maximum temperatures were reached in Western North America earlier than in the East. Warm air penetrated northwestern regions, allowing trees to grow farther north than they do today. By 10,000 years BP, trees were growing in today's tundra. After 6,500 years BP, the glacier disappeared in eastern Canada, and tree species began moving north into the Hudson Bay area around 3,500 years BP. The northern forest limit then was 175 miles north of the present forest edge. This broad expanse of woodland reverted to tundra as temperatures declined since then. This warming period (7,500 to 5,000 years BP) is referred to by a variety of names, including hypsithermal, Altithermal, xerothermic, or the Climatic Optimum (Pielou 1991).

The melting glaciers during the hypsithermal caused sea levels to rise, reaching present levels around 5,000 years BP. Across North America the increased warmth also dramatically affected tree species composition and distribution, reshuffling wildlife habitats and species (Edwards and Merrill 1977, Pielou 1991).

Vegetation Changes in the Southeast (the Early Holocene 9,500 to 7,500 Years BP)

Oak species already dominated the forest of the middle and lower Southeastern United States by 9,500 years BP; they have continued to dominate until present times. Hickories also were important. Southern pines were increasing and would later become a major component of the southeastern forest (Watts 1983). As boreal tree species migrated north, oaks and hickories became dominant in the upper South, extending into Virginia and Kentucky (Delcourt and others 1999, Edwards and Merrill 1977, Watts 1980) (fig. 24.12).

Southeastern coastal plant communities were probably unstable due to changing sea levels. Sea levels were constantly advancing on the land as the glacier melted. Pollen data indicate increasing presence of southern pine on the Coastal Plain. Disturbance, due to climatic instability, created open areas favorable for pine regeneration (Edwards and Merrill 1977, Spurr and Barnes 1973, Watts 1980).

The Southern Appalachians were also undergoing environmental changes. Increasing temperature shifted boreal spruce and fir to higher elevations, while lower elevations were occupied by mixed hardwoods species, with oaks as the dominant component (Delcourt and Delcourt 1985, Watts 1983). Mountainsides were eroding due to dying vegetation, resulting from unstable climatic conditions. Sediment from this erosive period was deposited in our modern floodplains (Chapman 1985).

The land area of Florida shrunk as the sea level rose. Fresh water was limited because water tables were still very low (Watts 1971). The southeastern climate was becoming warmer but remained dry until about 8,500 years BP when precipitation increased. Oaks were dominant as they had been during the Ice Age. Vegetation was composed of scrub oak, with increasing incidence of southern pines (Davis 1983, Delcourt and Delcourt 1984, Edwards and Merrill 1977, Milanovich and Fairbanks 1980, Watts 1983). As water tables stabilized by 5,000 years BP, forests assumed modern characteristics.

Unstable plant communities characterized the period of warming and deglaciation. Tree species were migrating from refuges occupied during the Ice Age. Some species moved fairly rapidly, while others migrated much more slowly (Davis 1983). Along with the changing vegetation was an increase in the frequency of fire, which is demonstrated by increased amounts of charcoal in pollen profiles (Delcourt 1985, Delcourt and others 1999, Watts 1980) (fig. 24.7). Fires were both natural and human-caused, but our ancestors were probably the predominant source of ignition that resulted in the increased fire frequency during selected seasons (Delcourt 1985, Delcourt and others 1999, Van Lear and Waldrop 1989). The combination of the migration of tree species, high erosion due to dying vegetation, and droughty growing seasons would not have favored a closed-canopy forest.

Oak, pine, and hickory are all relatively shade-intolerant, disturbance species that need openings and sunlight for regeneration. Increasing mean annual precipitation and closed-canopy forest would not have allowed these species to dominate the landscape for thousands of years, as indicated by pollen analyses (Delcourt and Delcourt 1985, Watts 1980). Mesic shade-tolerant species, such as beech and maple, would have dominated forests under a continuous closed-canopy forest. Therefore, the dominance of oak, pine, and hickory in the Southeast was due to frequent disturbance, which created open landscapes favorable for regeneration of shade-intolerant species (Fralish and others 1991). Increased fire frequency and climatic instability would have provided natural settings conducive to the dominance of oak, hickory, and southern pines (Abrams 1992, Brose and Van Lear 1997, Myers and Van Lear 1998).

The annual fires of prehistoric humans established and maintained the open forests, savannas, and prairies observed nearly 10,000 years later by the first European immigrants.

Wildlife Extinctions, Dwarfing, and Redistribution During the Early Holocene

The profound changes that were occurring in vegetation as the glaciers retreated also impacted wildlife species. Some wildlife species that were part of the southeastern Ice Age landscape became extinct or migrated to other regions, or out of North America entirely.

Faunal extinctions toward the end of the last glacial period (Pleistocene) and continuing into the Holocene were not the first wave of extinctions. According to Pielou (1991), at least six waves of extinctions have occurred during the Earth's history. Many of the extinctions have occurred at the end of glacial periods. The sixth wave ranked second in number of species extinctions and occurred at the end of the Pleistocene (Pielou 1991). Estimates of extinctions of mammals and birds between 20,000 to 7,000 years BP are as high as 17 genera (Hester 1960, Steadman and Martin 1984). The greatest numbers of extinctions occurred between 11,000 to 10,000 years BP (Martin 1967).

A number of paleoecologists have developed environmental models that depict rapidly changing ecosystems at the end of the Pleistocene as the cause of wildlife extinctions (Guilday 1982, Guthrie 1990, King and Saunders 1984). Early theories, developed during the mid-1800s, implicated humans in the extinctions at the end of the Pleistocene. However, it was not until Martin's (1967) "overkill theory" that our part in these extinctions was given serious consideration. However, a number of confounding factors, including changes in climate, habitat, and ecosystems, must have contributed to the demise of many species.

Another issue confounding the human "overkill theory" is humankind's long association in Eurasia with many of the species that became extinct at the end of the Pleistocene. Consider the wooly mammoth. Why didn't it disappear much earlier than it did in Eurasia? Clearly, our ancestors were hunting this species well before human entry into the Americas (Graham and Mead 1987, Grayson 1984, Pielou 1991).

Pielou (1991) hypothesized a natural catastrophe that reduced animal populations and from which they never fully recovered. He further contends that the great wave of extinctions at the end of the Pleistocene has not been convincingly explained (Graham and Mead 1987, Lundelius and others 1983, Semken 1983, Steadman and Martin 1984).

Radiocarbon studies suggest that some extinct North American wildlife species may have survived past 10,000 years BP. Semken (1983) proposed that mastodons, sabercats, sloths, dire wolves, horses, peccaries, and mammoths could have existed as late as 6,000 years BP. Support for these later dates came from the discovery of wooly mammoth remains on Wrangel Island north of the Bering Strait in Russia. These remains were radiocarbon dated to 3,700 years BP. A remarkable aspect of these remains was that these mammoths were only 4 feet tall (Vartanyen 1995).

Changing climate and vegetation during the late glacial and early Holocene caused relocation of wildlife. Species that existed in the Southeast during full and late glacial times adjusted to changing habitat. Elk, moose, and grizzly bear, which had migrated into North America about the same time as humans, moved north (Pielou 1991). Caribou migrated north, out of the Southeast, while species such as spectacled bears, llamas, tapirs, capybaras, and flat-headed peccaries migrated south and are now found only in South America. Jaguars may have migrated out of the Southeast much later. Some early colonists from the Carolinas describe a jaguar, in addition to the mountain lion. The use of the word "tyger" can be found in some early literature in the Southeast (Lefler 1967, Logan 1859), and in Latin America the jaguar is known as "el tigre". Porcupines and fishers may have inhabited parts of the Southeast until the 1600s; opossums and armadillos are now expanding their range northward (Semken 1983). The wooly mammoth, the Columbian mammoth, and American mastodon were declining in size prior to extinction. The Pleistocene black bear was the size of a small grizzly (Kurten 1988). Purdue (1989) reported a similar reduction in size for white-tailed deer during the Holocene. Guthrie (1990) documented a decline in the size of bison and also explains the appearance of the modern American bison from the merging of *Bison priscus* and *Bison occidentalis*.

Some animals once thought to have become extinct have been discovered living in small populations. The flat-headed peccary, thought extinct and once a resident of the Southeast, is alive in Paraguay. Also, a species of horse from the Pleistocene believed to be extinct has been found near Tibet. Sightings by natives in the Amazon report a sloth nearly 6 feet tall. Could this be a relative of giant sloth (Pearson 1995)?

The declining size of animals during the Holocene brings up an interesting question. Could the giant armadillo, giant beaver, giant sloth and other species of the Pleistocene have diminished in size to become our modern beaver, armadillo, and sloth?

What caused this dwarfing? Part of the answer may be drastic climatic and vegetation change. Guthrie (1990) postulates an increase in mesic species at the end of the Pleistocene. Mesic species are more toxic to herbivores, and the nutritional level of their foliage is lower. Deterioration of available nutrition would be an important change. Xeric plant species contain higher levels of nutrition, are more palatable, and were more ubiquitous during the drier climate of the Ice Age (Guthrie 1990). The small key deer is the same species as the white-tailed deer but is smaller because of limited nutrition.

Stress may have also been a factor in animal size. Rapidly changing ecosystems combined with human predation may have elevated stress levels in wildlife populations. The combination of changing habitats and human predation probably forced them into less favorable habitat, thereby contributing to nutritional deficits and dwarfing.

The extinction and disappearance of some animals apparently left an impression on the natives of the Southeast. Their stories indicate "things were not always as they are now, and in earlier times many of the large animals and beings of the 'Upper World' came down to live in 'This World.' But 'This World' grew progressively less ideal, and one by one the great animals and beings went back into the 'Upper World'" (Hudson 1976). Perhaps this tale, passed down through generations, relates the extinction process.

As vegetative communities shifted, and changes occurred in wildlife communities at the end of the Pleistocene, humans continued to thrive. Their increasing populations and increasing use of cultural tools and personal ornaments throughout this demanding period testify to their adaptability, ingenuity, and knowledge of the environment.

Early Archaic refers to the southeastern native culture during the early Holocene (Hudson 1976). Migratory hunting and gathering cultures continued into this period. However, there was a greater reliance on deer and smaller game. Spear points declined in size and became side notched. In addition, the number of spear points and tools increased in quantity. Smaller spear points signify a change in hunting technology toward deer and other small game. Archaeologists identify different cultures by the characteristics of spear points. Big Sandy spear points appeared early in the Southeast followed by the Kirk, Palmer, and Stanly spear points (Hudson 1976, Walthall 1980).

There is an apparent change in gathering techniques during this period. Large numbers of stone implements and other tools believed to have been used in the processing of nuts and wild vegetables have been uncovered.

Hypsithermal (7,500 to 5,000 Years BP)

The temperatures of the Hypsithermal peaked between 7,500 to 5,000 years BP and were higher than modern temperatures (fig. 24.13). Warming was experienced worldwide, and the Southeastern United States was no exception. Prairies expanded east of the Mississippi River and grasses increased in abundance, aided by native burning. In pollen samples from Missouri at 7,000 years BP, 85 percent of the species represented were grasses. This proportion of grass species is higher than those recorded for modern prairies (Culberson 1993). Accompanying the expanding prairies east of the Mississippi River were pronghorns and badgers. It is conceivable that the modern bison arrived as well (Culberson 1993, Guilday 1982), while the peccary disappeared from the Southeast (Goodyear and others 1979).

Changing vegetation and rapid deglaciation characterized the hypsithermal. Tree species were migrating from Ice Age refuges. More charcoal is mixed with pollen data due to increased burning by humans. Pines and oaks increase on the southeastern landscape (Delcourt and Delcourt 1985, Watts 1980). Only extensive openings and frequent disturbance from natural and native activities (burning, clearing stream bottoms, and gathering firewood) could explain the increase in pines.

During the hypsithermal, study sites in the Shenandoah, Potomac, and Savannah River Valleys indicated subdued flooding intervals. The data would indicate that the dry conditions were occasionally interrupted by wet intervals, which caused increased sedimentation at some locations. Evidence from some places in the Southeast would indicate oscillating periods of precipitation and temperature during periods of the hypsithermal. However, there is no indication of the season in which the precipitation fell. It is clear that the climate was generally drier and hotter during this period and that overall precipitation was low (Blanton and Sassaman 1989). Pollen data indicate that extraordinary vegetation changes occurred over large areas of the Southeast. Compounding the hotter, drier climate was the still lowered water table and lower sea levels as a result of incomplete thawing of the glaciers (Watts 1971).

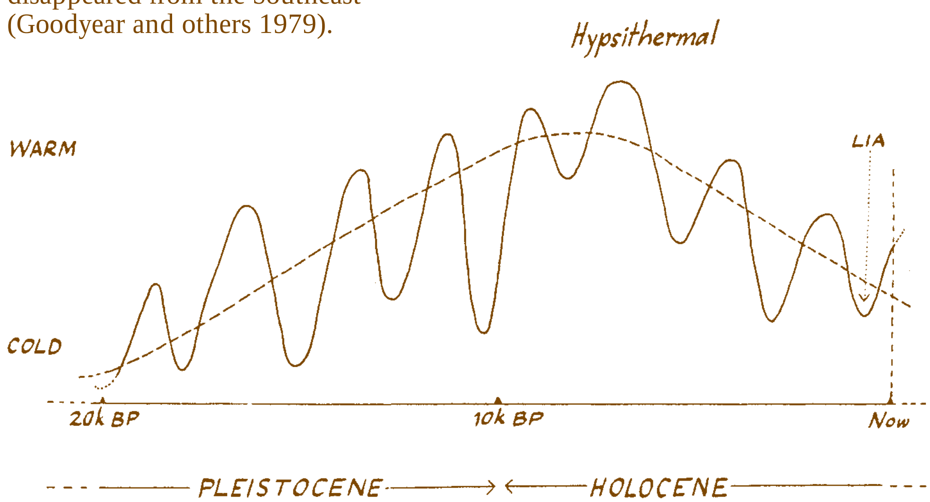


Figure 24.13—Rising temperatures after 7,500 yr BP (hypsithermal) melted the remnant Laurentide Ice Sheet by 6,500 yr BP. Trees reached the Hudson Bay in Canada, where treeless tundra exists today. After 5,000 yr BP, melting glaciers elevated oceans to present sea level. A cooling trend following the hypsithermal eventually led to the little ice age between 1400 and 1880 (modified Pielou 1991).

The Middle Archaic Period differs from the Early Archaic Period due to the continued climatic warming as the hypsithermal progressed. The Morrow Mountain and Guilford cultures were present during the Middle Archaic Period. Archaeological sites indicate a proliferation of Morrow Mountain spear points during this time (Walthall 1980). Food may have been less predictable, elevating competition for resources. Artifacts from these cultures were more crudely made; and settlement sites were small and scattered, possibly due to more frequent relocation resulting from resource scarcity or lack of predictability. However, in the face of severe climatic changes, native populations increased and territories became more defined.

Archaeologists have uncovered evidence of increased external and internal conflict at Kentucky Knoll in Kentucky, the Eva site in Tennessee, and several sites in Alabama. Most conflicts centered around riverine shell-gathering and fishing sites (Walthall 1980). Human activities in coastal areas of the Southeast are poorly documented during this time, possibly due to unstable coastal ecosystems and rising oceans. Subsistence activities appear to be the same as in earlier archaic people. Scattered and scarce resources and increased human populations may have increased conflict between groups.

The Cooling Trend (5,000 to 120 Years BP)

By 5,000 years BP, a global cooling trend caused a major retraction of vegetation communities to their modern locations and halted rising sea levels. The wetlands of the Southeast stabilized at this time and would slowly develop into our present wetland communities. The cooling trend would culminate in a period known as the Little Ice Age, 600 to 120 years BP (1400 to 1880). This event caused a minor retraction and set the stage for modern plant assemblages (Davis 1983).

Oak and pine were dominant over most of the Southeast, due mainly to human activities and other natural disturbances. Native burning regimes increased populations, and native agriculture began to shape the landscape witnessed by the first European immigrants.

Figure 24.14—Meso-America: dashed brown lines mark the boundaries of the Meso-American cultures where complex societies began to develop as early as 4,500 yr BP. Domestication of certain plants, particularly maize, led to sophisticated agricultural systems. By 1500, there may have been 10 million people in this region (modified from Smith 1996).

Following the high temperatures of the hypsithermal, global cooling and the trend toward stable vegetation communities also created a cultural change in the Southeast. This archaeological period is known as the Late Archaic Period (5,000 to 2,800 years BP). The climate and vegetation were similar to their modern equivalents. Population markedly increased and settlements stabilized. As riverine ecosystems reached modern stability, settlements became closely tied to these areas. Mussel gathering and fishing increased, while hunting and gathering followed earlier patterns. There was a great increase in material culture associated with the sedentary way of life. Large steatite and sandstone bowls, increased chipped-stone, ground stone, bone and antler implements, and personal ornaments indicate a developing culture (Goodyear and others 1979, Hudson 1976, Walthall 1980). The bow and arrow were introduced to the Southeast from the Midwest, and even though it did not change subsistence activities, it was a technological advance. Around 4,500 years BP the first pottery appears. It was invented in Florida and South Carolina at about the same time. The invention of pottery reflects the trend away from a more nomadic culture.

A Late Archaic culture known as the Savannah River culture dominated most of the Southeast. What is important about this culture is the increased utilization of floodplains throughout the region. Fire continued to be used to attract or drive game; and after 4,500 years BP, fire was applied to clear floodplain vegetation. Pollen cores taken at a variety of sites in the Southeast indicate increased wood charcoal and early successional herbaceous and tree species (Delcourt and Delcourt 1985). Annual clearing of floodplains was necessary to cultivate important plants, such as squash, gourds, sunflower, sumpweed, and chenopodium (Hudson 1976). Floodplains were cleared to accommodate growing native settlements. Extensive areas of open land, a defensive scheme for protection from unfriendly tribes, surrounded expanded settlements. Higher populations required more firewood, increasing demands on surrounding forests and further enlarging forest clearings.

Larger populations are associated with an increase in social and political structure. These processes culminated in a new cultural period, the Woodland period.

Woodland Culture (2,800 to 1,300 Years BP)

Widespread pottery making, horticulture, and semipermanent settlements mark the Woodland culture. Hunting and gathering methods remained traditional with one major change—the use of the bow and arrow. This tool improved deer harvesting. Arrowheads representative of this period are found throughout the Southeast. Yadkin points were widespread in the region early. Other styles, such as Madison, Santa Fe, Scallorn, and Agee, followed the Yadkin points.

A small-eared form of maize was cultivated from 2,200 to about 1,600 years BP but disappeared because of global cooling. Populations continued to grow, increasing tribal identity, and indicating stronger socio-political systems than in the past (Hudson 1976). Trade between peaceful tribes flourished throughout the Southeast and developed with the larger civilizations in Mesoamerica (fig. 24.14). As Mesoamerican influence gradually displaced Woodland cultures over large areas of the Southeast, the Mississippian culture emerged. However, Woodland cultures continued in Virginia and most of North Carolina. Much of Kentucky became uninhabited around the first century (2,000 years BP) due to migration of tribes to the east and west as a result of aggressive pressure from Algonquian Tribes from the north (Merrell 1982).

Mississippian Culture (1,300 to 400 Years BP)

The cultivation of the tropical maize, flint corn, and beans along the Mississippi River and in the Gulf States marks the beginning of the Mississippian culture. This culture became fully developed in the Southeast around 1,300 years BP and continued until the arrival of Europeans. The adopted intensive agricultural practices from Mesoamerica influenced the landscape in the Southeast dramatically. Large native populations developed in much of the lower South because of the more sophisticated agricultural system produced more food. Without draft animals or plows, agriculture with stone or wood implements was limited to the tillable soils of floodplains, where spring flooding helped renew soil fertility. Agricultural fields were cleared first by girdling trees and then burning the area. The ashes acted as fertilizer (Swanton 1946). Stumps were also removed over time and in the spring old agricultural debris was burned off before planting (Doolittle 1992). When soil fertility declined from cultivation, fields lay fallow but were burned annually to maintain their open condition for future agricultural use. Most of the cultivatable floodplains of the Southeast were cleared of forest and managed in this way (Doolittle 1992, Hudson 1976).

All over the Southeast, land was cleared for large villages, hamlets, agricultural fields, and groves of fruit-bearing trees. In addition, towns moved every few decades because of soil and firewood depletion. Over time, new towns were built on old town sites, which were kept open by annual burning (Hudson 1976).

Clearing floodplains and upper terraces for agriculture and village sites across the South increased as the Mississippian culture spread. Central towns covered hundreds of acres and included expansive plazas and religious centers. Central towns were dominated by extensive public works of truncated mounds topped by temples. One such town, Cahokia, near St. Louis, MO, is estimated to have had a population of nearly 50,000. It was abandoned when firewood and soil were depleted.

There were large organized political centers, or chiefdoms, such as Cahokia, scattered throughout the Southeast. These chiefdoms were similar to city-states and demanded tribute from surrounding vassal tribes. They also waged war and competed with other chiefdoms to secure hunting and agricultural lands to support their large and growing populations. The successful Mississippian culture spread across the Southeast, up the Mississippi River Valley around 900, and then east into South Carolina around 1100 (fig. 24.15). Native populations in the Southeast increased dramatically during this period, and by 1500 it is estimated that 1.5 to 2 million people lived in the Southeast (Dobyns 1983). These chiefdoms were still in place to receive the first Spanish explorers in the 1500s (Goodyear and others 1979, Hudson 1976, Walthall 1980, Ward and Davis 1999). Old World diseases introduced by the Spanish in the early 1500s decimated the American Indian populations of the Southeast. Around

Figure 24.15—Mississippian cultural areas and some important chiefdoms [note direction of expansion (modified from Hudson 1976)].

1600 the Mississippian culture collapsed (Smith 1987).

The Native Ecosystem

For a minimum of 12,000 years, American Indians had been skillfully manipulating the environment, primarily with fire. Human activity was unique during each cultural period, and books could be written on the various periods. The landscapes that the first Europeans encountered were not undisturbed, dense forests as many people today envision. Knowledgeable humans skillfully modified the landscapes to support a population numbering in the millions at the time of European contact. Pollen analysis and historical eyewitness accounts depict a disturbed landscape consisting of a mosaic of open and uneven-aged forests, native settlements, agricultural land, and prairies, which were the direct result of American Indian activity and natural disturbances.

During the long duration of human history in the Americas, the natives developed intimate understanding of the land, forest, plants, and animals. They domesticated plants that are still widely used in agriculture throughout the world. Hudson (1976) estimates that southeastern Indians may have used as many as 500 species of plants for medicinal purposes and that they were successful for treating medical problems. The natives had developed food procurement methods based on seasonality of resources and planned their societies around knowledge of resource availability. Continuous and intimate observations of natural cycles allowed them to understand the complex workings of their ecosystems. Natives were well aware of land management activities that produced abundant fruits, nuts, and wildlife forage in specific locales.

Biological Evidence for Native Burning

There is ample biological evidence to corroborate written historical records by early Europeans that describe the disturbed southeastern landscapes and American Indian's widespread use of fire. The unambiguous dominance of oak, pine, and hickory in the pollen record for thousands of years confirms the presence of uninterrupted fire-disturbed forest ecosystems in the Southeast. Fralish and others (1991) compared the characteristics of presettlement forests to existing old growth forest remnants in the same area using witness trees of an 1806-07 land survey in the Southeast. He found that trees in presettlement forests were more widely spaced and were of larger diameter than trees in existing old growth stands. On dry ridgetops, presettlement trees were shorter with wider crowns, whereas existing old growth trees are taller with smaller crowns due to crowding. Oak and hickory dominated presettlement forests; they are being succeeded by mesic shade-tolerant species in existing old growth. Fire-sensitive redcedar is more prevalent in existing old growth than it was in presettlement forests. This study supports the premise of fire-disturbed presettlement forests dominated by oak and hickory or pines on an open landscape of more widely spaced trees.

The vast longleaf pine ecosystem throughout the southeastern Coastal Plain furnishes additional support for the premise of widespread use of frequent fire by southeastern natives. The longleaf pine ecosystem ranged from Virginia's southeastern Coastal Plain across the eastern and Gulf Coastal Plains to eastern Texas (Landers and others 1995). This ecosystem was distinguished by widely spaced trees, which created an open, park-like pine barren (fig. 24.16). The large expanse of the longleaf pine ecosystem was composed of even-aged and multi-aged mosaics of forest, woodland, and savanna, with a diverse, low ground cover dominated by bunch grasses. Understory hardwoods and shrubs occupied wet areas that did not burn frequently. Longleaf pine is the key tree species in this complex, fire-dependent ecosystem. Without frequent fire, other species slowly dominate these stands (Landers and others 1995). This ecosystem originated after 9,500 years BP as a result of native burning, which created an ecosystem that also encouraged natural lightening fires, due to the nature of the vegetation community.

Species diversity in these savannas is the highest reported in North America (Westhoff 1983). Burned areas contain seven times more plants valuable to wildlife than unburned area. Fire in these ecosystems substantially increases protein content, nutrients, and palatability of forage (Komarek 1983). Longleaf pine seeds are also an excellent wildlife food. It is not difficult to understand the motivations for developing these prime ecosystems for food procurement.

The Native Ecosystem as Witnessed by the Early Europeans

When Europeans arrived, the landscape of the Southeast was a mosaic of open pine and hardwood woodlands, prairies, meadows, and oak or pine savannas in a variety of

Figure 24.16—A view of the longleaf pine-wire grass ecosystem.

successional forest stages. In addition to American Indian influence on vegetation, natural events, such as hurricanes, thunderstorms, ice storms, insects, and diseases, constantly disturbed the vegetation of the Southeast (Conzen 1990, Myers and Van Lear 1998). Oaks, southern pines, and hickories were dominant tree species almost everywhere. Pine barrens or savannas with scattered oaks dominated large areas of the Coastal Plain. Oak, pine, and hickory forests were dominant in the upland areas across the middle and upper South. The Appalachian Summit was also dominated by oaks but had a mixture of other important hardwoods, such as American chestnut, hickories, maples, poplars, and residual boreal species (Delcourt and Delcourt 1984, 1985; Watts 1980, 1983).

This landscape supported a diversity and abundance of wildlife, such as deer, turkey, bear, elk, bison, wolves, mountain lions, and myriad smaller mammals. Nonmigratory and migratory birds were abundant throughout the region. Early writers talked about the abundance of passenger pigeons, where flocks in flight would literally block out the sun. Beaver impoundments and other wet areas supported mesic trees, shrubs, and a diversity of hydric plants, such as sedges, rushes, and cattails, while providing habitat for waterfowl, other birds, mammals, and reptiles. Wetlands in the Coastal Plain also supported stands of baldcypress, swamp tupelo, water tupelo, sweetgum, along with oaks and other hardwoods.

Early Spanish explorers remarked about the open nature of forests, prairies, and savannas, and the extensive cultivated fields and groves of fruit-bearing trees extending for miles over the landscape. The settlers were in consensus about the ease of travel through the forest even on horseback and were able to move large groups of people, horses, and livestock easily through the landscape (Doolittle 1992, Gremillion 1987).

English settlers and explorers confirmed the Spanish accounts with similar descriptions of the landscape. They also witnessed burning by the natives. As one English settler wrote in 1630, on approaching the Delaware coast, "the land was smelt before it was seen", referring to the smell of smoke (Cowdrey 1983). This settler would remark on the openness of the forests, and what this settler saw and "smelt" was the typical scene all over the Southeast (Barden 1997, Byrd 1928, Cumming 1958, Hartley 1977, Lefler 1967, Leyburn 1962, Logan 1859, Platt and Brantley 1997, Rostlund 1957).

Those unfamiliar with the rapid development of dense understories in unburned forests of the South would soon appreciate the motivation of the natives to manage their land with fire. This is true for every southern ecosystem from the coast to the mountains. In the absence of fire, any means of travel becomes impossible as small hardwoods combine with shrubs to create dense, impassable thickets.

Early writers ignored the eyewitness accounts and opted for a more romanticized description of this dynamic landscape, describing a pristine closed canopy forest where a squirrel could travel from the Atlantic Coast to the Mississippi River without touching the ground. This romantic description is a myth (Buckner 1983). An equally romanticized picture was also painted of the natives.

Decline of Native Populations

When Christopher Columbus' three ships anchored off the coast of San Salvador, little did anyone, European or native, realize the magnitude of the impacts of the Old World meeting the New. The Spanish, who sponsored Columbus, were initially attracted to the wealth of the large complex societies of Mesoamerica. Rumors led the Spanish to believe that similar societies existed in the Southeast. Early in the 1500s, Spanish expeditions probed deep into the Southeast.

Some of the first estimates of pre-European native populations in the Southeast occurred in the early 1900s (Kroeber 1939). They were based on early English accounts, following dramatic population declines that resulted in the low estimates. Pre-European native populations of the Southeast were substantial. More recent estimates such as Dobyns (1983), have postulated larger populations not only for the Southeast, but also for the entire Western Hemisphere. Dobyns (1983) estimates native populations in the Southeast at 1.5 to 2 million people at 1500. Today population estimates are based on greater understanding of the impacts of epidemics along with the increased knowledge of the complex civilizations of the Mississippian chiefdoms.

European expeditions introduced Old World diseases that would shake the foundations of every American Indian culture in the Western Hemisphere. Of all the organisms Europeans carried to America, none were more devastating to southeastern Natives than Old World diseases (Hudson 1976, Smith 1987).

Before 1492, America was not disease free, but native diseases derived from the age-old human problems of population density, diet, and sanitation. During the period of European contact, disease-related mortality rose to levels previously unknown; and the impact of these diseases was swift and harsh. In areas of the Caribbean, entire native populations were erased. These epidemic diseases were transported from the Caribbean to Mexico and Central America and may have preceded the arrival of the Spanish in these areas (Lovell 1992, Verano and Ubelaker 1992). Epidemic diseases were introduced to the natives of the Southeast at about the same time (Thornton and others 1992). During the 100 years of Spanish exploration, disease decimated the dominant Mississippian cultures of the Southeast and resulted in their collapse by 1600 (Smith 1987).

European diseases not only depopulated American Indian cultures (depopulation is estimated as high as 90 to 95 percent), they disrupted the social structure of native societies. As in all epidemics, mortality was disproportionably greater among the young and old. Loss of the younger generation had profound effects on the integrity of American Indian societies. The loss of manpower created difficulties maintaining agricultural systems and fire regimes. Loss of the elderly eliminated a storehouse of knowledge, tradition, and custom (Hartley 1977, Hudson 1976, Smith 1987).

The arrival of the English continued the epidemic diseases and decimation of American Indians for at least another century. English trade with the natives lured them into dependence on the European fur market for European goods, which in turn diminished the traditional reasons for hunting, while devastating wildlife populations

(Hartley 1977, Hudson 1976, Smith 1987). As the fire regimes and agricultural systems gradually eroded, the appearance of the land began to change. Uncontrolled vegetation began to form an unbroken shroud. The extensive canelands witnessed by English settlers as they pushed inland were signs that the thousands-of-years-old fire ecosystems created by the natives were in decline (Platt and Brantley 1997).

Potential Forest Vegetation?

E.L. Braun (1950) developed a generalized map of potential major modern forest types for the Eastern United States (fig. 24.2). The map was developed from surveys to project potential forest species compositions that best characterize the eastern forest region. Braun's classic study is still an important standard for vegetation maps today. Paleoecologists have produced generalized vegetation maps for periods in the past. Delcourt and Delcourt (1984) produced a vegetation map for dominant plant species occurring 18,000 years ago (fig. 24.1). When Braun's modern vegetation map is compared to the Delcourts' map of vegetation, it is evident that dramatic changes have occurred. The presence of glaciers 18,000 years ago, and their absence now, account for much of the difference.

Eighteen thousand years ago the southeastern landscape was powerfully influenced by a massive glacial ice sheet, which created an unusually dry climate. This dry climate limited tree distribution and growth and was conducive to frequent and widespread fire. The glacier's subsequent retreat resulted in extreme continental temperatures, changing sea levels, and disrupted vegetation and wildlife communities. The arrival of humans about 12,000 years BP and their use of fire in the Americas complemented the natural fire regimes. The dominance of oak, hickory, and southern pines throughout much of the Southeast is due to extensive disturbance by humans and nature for millennia. In fact, the vegetation composition and distribution, which complemented the diversity and abundance of wildlife at the time of European contact, was primarily the result of American Indian management of southern landscapes with frequent burning for over 12,000 years.

Because of fire exclusion during much of the recent past and the public's desire for undisturbed forests, unprecedented changes in vegetation composition and distribution are occurring across the Southeast. Oaks, hickories, and pines can survive for hundreds of years in the overstory, but will they remain dominant in our forests without fire? Oaks do not regenerate in extant oak stands on high-quality sites; rather, they convert to more shade-tolerant species (Loftis and McGee 1993). In the absence of disturbance, oaks are not able to regenerate and will not maintain their historical dominance (Abrams 1992, Brose and Van Lear 1998, Loftis and McGee 1993). In the Southern Appalachians, cove forests and upper ridges are increasingly dominated by dense understories of shade-tolerant shrub species, such as rhododendron and mountain laurel, which out compete shade-intolerant oaks, hickories, and southern pines (Baker and Van Lear 1998, Elliot and Hewitt 1997, Hedman and Van Lear 1995). Without disturbance, beech, maples, and other shade tolerant species will gradually dominate southern forests. In the southern Coastal Plain, the once dominant fire-dependent longleaf pine type now occupies less than 3 percent of its original range (Landers and others 1995).

The “potential” or “natural” vegetation map developed by Braun (1950) is a reflection of the Clementsian model of forest succession that dominated ecological thought until the mid-1950s. This model considered disturbance as a relatively unimportant event in the long-term order. However, ecologists now recognize the importance of disturbance. It has been disturbance, repeated over and over for thousands of years, on different temporal and spatial scales that led to the dominance of oaks, hickories, and southern pines in southeastern landscapes and provided the habitats that supported diverse and abundant wildlife populations.

Literature Cited

Abrams, M.D. 1992. Fire and the development of oak forests. Bioscience. 42: 346–353.

Anderson, David G. 1991. Examining prehistoric settlement distribution in Eastern North America. Archaeology of Eastern North America. Bethlehem, CT: Eastern States Archaeology Federation. 19: 1–22.

Anderson, David G.; Faught, Michael K. 1998. The distribution of fluted Paleoindian projectile points: update 1998. Archaeology of Eastern North America. Bethlehem, CT: Eastern States Archaeology Federation. 26: 163–187.

Andrews, John T. 1987. The Wisconsin glaciation and deglaciation of the Laurentide ice sheet. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 13-37. Vol. K-3.

Baker, T.T.; Van Lear, D.H. 1998. Relations between density of rhododendren thickets and diversity of riparian forests. Forest Ecology Management. 109: 21–32.

Barden, Lawrence S. 1997. Historic prairies in the Piedmont of North and South Carolina. Natural Areas Journal. 17: 149–152.

Barry, R.G. 1983. Late Pleistocene climatology. In: Wright, H.E., Jr.; Porter, Stephen C., eds. The late-quaternary environments of the United States, the late Pleistocene. Minneapolis: University of Minnesota Press. 1: 390-407. Vol. 1.

Bendell, J.F. 1974. Effects of fire on birds and mammals. In: Kozlowski, T.T.; Ahlegren, C.E., eds. Fire and ecosystems. New York: Academic Press, Inc. 542 p.

Blackburn, W.E.; Kirk, J.P.; Kennamer, J.E. 1975. Availability and utilization of summer foods by eastern wild turkey broods in Lee County, Ala. In: Halls, L.K., eds. Proceedings: third national wild turkey symposium, Texas chapter. The Wildland Society. 3: 86–107.

Blanton, Dennis B.; Sassaman, Kenneth E. 1989. Patterns and process in the middle archaic period of South Carolina. In: Studies in S.C. archaeology, anthropological studies 9. Occas. Pap. of the South Carolina Institute of Archaeology and Anthropology. Columbia, SC: University of South Carolina. [Number of pages unknown].

Bonnichsen, Robson; Standford, D.; Fastook, J.L. 1987. Environmental change and developmental history of human adaptive patterns: the Paleoindian case. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 403-424. Vol. K-3.

Braun, E.L. 1950. The phytogeography of unglaciated Eastern United States and its interpretation. Botanical Review. 21: 297–375.

Brose, P.H.; Van Lear, D.H. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Canadian Journal of Forest Research. 28: 331–339.

Buckner, E. 1983. Archeological and historical bases for forest succession in Eastern North America. In: Proceedings: 1982 Society of American Foresters national convention. [Washington, DC]: SAF Publications: 83–104.

Byrd, William. 1928. A journey to the land of Eden. New York: Macy-Massius. 367 p.

Catesby, Mark. 1731-1743. The natural history of Carolina, Florida, Bahama Islands. Savannah, GA: Beehive Press. 107 p. [Reprinted 1974].

Champion, T.; Gamble, C.; Shennan, S.; Whittle, A. 1984. Prehistoric Europe. London: Academic Press, Inc. 359 p.

Chapman, Jefferson. 1985. Tellico archaeology. Rep. invest. 43. Knoxville, TN: University of Tennessee. 135 p.

Coe, Joffre L. 1952. The cultural sequence of the Carolina Piedmont. In: Griffen, James B., ed. Archaeology of Eastern United States. Chicago: University of Chicago. 392 p.

Conzen, Michael P. 1990. The making of the American landscape. Chicago: The University of Chicago Press. 433 p.

Coon, Carleton S. 1954. The story of man. New York: Alfred A. Knopf. 437 p.

Cotter, John L. 1991. Update on Natchez man. American Antiquity. 56: 36–39.

Cowdrey, Albert E. 1983. This land this South, an environmental history. Louisville, KY: University of Kentucky Press. 236 p.

Culberson, Linda Crawford. 1993. Arrowheads and spearpoints in the prehistoric Southeast. [Place of publication unknown]: University of Mississippi Press. 117 p.

Cumming, W.P. 1958. The discoveries of John Lederer. Charlottesville, VA: University of Virginia Press. 148 p.

Davis, J.R. 1976. Management for Alabama wild turkey. Spec. Rep. 5. [Place of publication unknown]: Alabama Department of Conservation. 130 p.

Davis, Margaret B. 1983. Holocene vegetational history of the Eastern United States. In: Wright, H.E., Jr., ed. Late-Quaternary environments of the United States, the Holocene. Minneapolis: University of Minnesota Press: 166-181. Vol. 2.

Delcourt, P.A.; Delcourt, H.R. 1979. Late Pleistocene and Holocene distributional history of the deciduous forest in the Southeastern United States. Zurich, Germany: Veroffentlichugen des Geobotanischen Institues der ETH. 68: 79–107.

Delcourt, P.A.; Delcourt, H.R. 1984. Late Quaternary paleoclimates and biotic responses in Eastern North Atlantic Ocean. Paleogeogr., Palaeoclimatol., Palaeoecol. Amsterdam, Netherlands: Elsevier Science Publishers B.V. 48: 263–284.

Delcourt, P.A.; Delcourt, H.R. 1985. Quaternary palynology and vegetational history of the Southeast United States. Program for Quaternary studies of the Southeast U.S. Knoxville, TN: University of Tennessee. 28 p.

Delcourt, P.A.; Delcourt, H.R.; Ison, C.R. [and others]. 1999. Forests, forest fires, and their makers. Ser. 4. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 29 p.

De Vorsey, Louis, Jr. 1971. De Brahm's report (1764) of the general survey in the southern district of North America. Columbia, SC: University of South Carolina Press. 323 p.

Dobyns, H.F. 1983. Their number became thinned: Native American population dynamics in Eastern North America. Knoxville, TN: University of Tennessee Press. 378 p.

Doolittle, W.E. 1992. Agriculture in North America on the eve of contact: a reassessment. Annals of the Association of American Geographers. 82: 386–401.

Dragoo, Don W. 1976. Some aspects of Eastern North American prehistory: a review. American Antiquity. 41: 3–27.

Edwards, R.L.; Merrill, Arthur S. 1977. A reconstruction of the Continental Shelf areas of Eastern North America for the times 9,500 BP and 12,000 BP. Archaeology of Eastern North America. Bethlehem, CT: Eastern States Archaeology Federation. 5: 1–43.

Elliott, Katherine J.; Hewitt, Deidre. 1997. Forest species diversity in upper elevation hardwood forests in the Southern Appalachian Mountains. Castanea. 62(1): 32–42.

Fagan, Brian M. 1987. The great journey, the peopling of ancient America. New York: Thames and Hudson, Inc. 288 p.

Fralish, J.S.; Crooks, F.B.; Chambers, J.L.; Hartly, F.M. 1991. Comparison of presettlement forest, second-growth, and old-growth forest on six site types in the Illinois, Shawnee Hills. American Midland Naturalist. 125: 294–309.

Goodyear, Albert C. 1982. The chronological position of the Dalton horizon in the Southeastern United States. American Antiquity. 47(2): 382–395.

Goodyear, Albert C., III; House, John H.; Ackerly, Neal W. 1979. Laurens-Anderson: an archaeological study of the South Carolina inter-riverine Piedmont. Anthropol. Stud. 4, Occas. Pap. of the South Carolina Institute of Archaeology and Anthropology. Columbia, SC: University of South Carolina. 316 p.

Graham, Russell W.; Mead, Jim I. 1987. Environmental fluctuations and evolution of mammalian faunas during the last deglaciation in North America. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 371-402. Vol. K-3.

Grayson, D.K. 1984. Nineteenth-century explanations of Pleistocene extinctions: a review and analysis. In: Martin, P.S.; Klein, R.G., eds. Quaternary extinctions; a prehistoric revolution: Tucson, AZ: University of Arizona Press: 5–9.

Gremillion, Kristen Johnson. 1987. Plant remains from the Fredericks, Wall sites. In: Dickens, R.S., Jr.; Ward, H.T.; Stephen Davis, R.P., Jr., eds. The Siouan Project: seasons I and II. Chapel Hill, NC: University of North Carolina, Anthropology Department: 275–277.

Guilday, John E. 1982. Appalachia 11,000–12,000 years ago. Archaeology of Eastern North America. Bethelehem, CT: Eastern States Archaeology Federation. 10: 22–25.

Guthrie, Dale. 1990. Frozen fauna of the Mammoth Steppe. Chicago: University of Chicago Press. 323 p.

Hartley, Marvin Thomas, III. 1977. The dividing path: the direction of Cherokee life in the eighteenth century. Chapel Hill, NC: University of North Carolina. 119 p. M.S. thesis.

Hedman, C.W.; Van Lear, D.H. 1995. Vegetative structure and composition of Southern Appalachian riparian forests. Bulletin of the Torrey Botanical Club. 122: 134–144.

Hester, J.J. 1960. Pleistocene extinctions and radiocarbon dating. American Antiquity. 26: 58–77.

Hoebel, E. Adamson. 1972. Anthropology: the study of man. 4th ed. New York: McGraw-Hill, Inc. 756 p.

Hudson, Charles. 1976. The south-eastern Indians. Knoxville, TN: The University of Tennessee Press. 573 p.

Hughes, T. 1987. Ice dynamics and deglaciation models when ice sheets collapsed. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 183–220. Vol. K-3.

Jacobson, G.L., Jr.; Webb, T., III; Grimm, E.C. 1987. Patterns and rates of vegetation change during the deglaciation of Eastern North America. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 277–288. Vol. K-3.

King, J.E.; Saunders, J.J. 1984. Environmental insularity and the extinction of the American mastodont. In: Martin, P.S.; Klein, R.G., eds. Quaternary extinctions: a prehistoric revolution. Tucson, AZ: University of Arizona Press: 315–344.

Komarek, E.V. 1983. Fire as an anthropogenic factor in vegetation ecology. In: Holzner, W.; Werger, M.T.A.; Ikusima, I., eds. Man's impact on vegetation. The Hague, Netherlands: Dr. W. Junk: 77-82.

Kroeber, A.L. 1939. Cultural and natural areas of native North America. Berkeley, CA: University of California Publications in American Archaeology and Ethnology. 38: 1–242.

Kurten, Bjorn. 1972. The ice age. New York: G.P. Putnam & Sons. 179 p.

Kurten, Bjorn. 1988. Before the Indians. New York: Columbia University Press. 158 p.

Kutzbach, J.E. 1987. Model simulations of the climatic patterns during the deglaciation of North America. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 425-446. Vol. X-3.

Landers, J. Larry; Van Lear, David H.; Boyer, William D. 1995. The longleaf pine forests of the Southeast: requiem or renaissance? Journal of Forestry. November: 39–44.

Lee, Richard B.; DeVore, Irven. 1968. Man the hunter. Chicago: Aldine Publishing Co. 415 p.

Lefler, Hugh T., ed. 1967. John Lawson's: a new voyage to Carolina. Chapel Hill, NC: University of North Carolina Press. 305 p.

Leyburn, James G. 1962. The Scotch-Irish, a social history. Chapel Hill, NC: University of North Carolina. 206 p.

Loftis, D.L.; McGee, C.E., eds. 1993. Oak regeneration: serious problems, practical recommendations. In: Proceedings of a symposium. Gen. Tech. Rep. SE–84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 319 p.

Logan, J.H. 1859. A history of the upper country of South Carolina, from the earliest periods to the close of the War of Independence. Charleston, SC: Courtney Co. 521 p.

Lovell, George W. 1992. Heavy shadows and black night: disease and depopulation in colonial America. Annals of the Association of American Geographers. 82(3): 426–443.

Lundelius, Ernest L., Jr.; Graham, Russell W.; Anderson, Elaine [and others]. 1983. Terrestrial vertebrate faunas. In: Wright, H.E., Jr.; Porter, Stephen C., eds. The late-quaternary environments of the United States, the late Pleistocene. Minneapolis: University of Minnesota Press: 311–353. Vol. 1.

Martin, P.S.; Mehringer, P.J., Jr. 1965. Pleistocene pollen analysis and biogeography of the Southwest. In: Wright, H.E., Jr.; Frey, David G., eds. The Quaternary of the United States. Princeton, NJ: Princeton University Press: 433–451.

Martin, Paul S. 1967. Prehistoric overkill, in Pleistocene extinctions: the search for a cause. In: Martin, P.S.; Wright, H.E., Jr. Proceedings of the seventh congress of the International Association for Quaternary Research. New Haven, CT: [Publisher unknown]. 6: 453.

Maxwell, J.A. 1984. America's fascinating Indian heritage. In: Maxwell, James A., ed. Pleasantville, NY: The Reader's Digest Association, Inc. 416 p.

Merrell, James H. 1982. Natives in the New World: the Catawba Indians of Carolina, 1650–1800. Ann Arbor, MI: University of Michigan. 696 p. 2 vol. Ph.D. dissertation.

Mickelson, D.M.; Clayton, L.; Fullerton, D.S.; Borns, H.W., Jr. 1983. The late Wisconsin glacial record of the Laurentide ice sheet in the United States. In: Wright, H.E., Jr.; Porter, Stephen C., eds. The late-quaternary environments of the United States, the late Pleistocene. Minneapolis: University of Minnesota Press: 3–37. Vol. 1.

Milanovich, Jerald; Fairbanks, Charles H. 1980. Florida archaeology, early hunters and foragers: Paleo-Indian and archaic peoples. New York: Academic Press. 290 p.

Mooney, James. 1900. Myths of the Cherokees. 19th annual rep. Washington, DC: Bureau of Ethnology. 397 p.

Myers, R.K.; Van Lear, D.H. 1998. Hurricane-fire interactions in coastal forests of the South: a review and hypothesis. Forest Ecology Management. 103: 265–276.

Parfit, Michael. 2000. Dawn of humans. Washington, DC: National Geographic Society. 198(6): 40–67.

Pearson, Stephanie. 1995. Load the stun gun, pass the old spice. Outside Magazine. XX(11): 34.

Pielou, E.C. 1991. After the ice age. Chicago: University of Chicago Press. 366 p.

Platt, Steven G.; Brantley, Christopher G. 1997. Canebrakes: an ecological and historical perspective. Castanea. 62(1): 8–21.

Purdue, James R. 1989. Changes in the Holocene in the size of white-tailed deer (*Odocoileus virginianus*) from central Illinois. Quaternary Research. 32: 307–316.

Roosevelt, Anna Curtenius. 2000. Who's on first? Natural History Magazine. 109(6): 76–79.

Rostlund, E. 1957. The myth of a natural prairie in Alabama: an interpretation of historical records. Annals of the Association of American Geographers. 47: 392–411.

Semken, Holmes A., Jr. 1983. Holocene mammalian biogeography and climatic change in the Eastern and Central United States. In: Wright, H.E., Jr., ed. Late-Quaternary environments of the United States, the Holocene. Minneapolis: University of Minnesota Press: 182–207. Vol. 2.

Smith, Marvin T. 1987. Archaeology of aboriginal culture change in the Interior Southeast: depopulation during the early historic period. Gainesville, FL: University of Florida Press. 185 p.

Smith, Michael E. 1996. The Aztecs. Malden, MA: Blackwell Publishers, Inc. 361 p.

Spurr, Stephen H.; Barnes, Burton V. 1973. Forest ecology. 2d ed. New York: The Ronald Press Co. 571 p.

Steadman, D.W.; Martin, P.S. 1984. Extinction of birds in the Pleistocene of North America. In: Martin, P.S.; Klein, R.J., eds. Quaternary Extinctions: 466–477.

Swanton, John. 1946. The Indians of the Southeastern United States. Bull. 137. [Washington, DC]: Bureau of American Ethnology, Smithsonian Institution. 993 p.

Thornton, Russell; Warren, Jonathan; Miller, Tim. 1992. Depopulation in the Southeast after 1492. In: Verano, J.W.; Ubelaker, D.H., eds. Disease and demography in the Americas. Washington, DC: Smithsonian Institution Press. 294 p.

Van Lear, D.H.; Waldrop, T.A. 1989. History, uses, and effects of fire in the Appalachians. Gen. Tech. Rep. SE–54. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 20 p.

Vartanyen, S.L.; Arslanov, K.A.; Tertychnaya, T.V.; Chernov, S.B. 1995. Radiocarbon dating evidence for mammoths on Wrangel Island, Arctic Ocean, until 2000 B.C. Tucson, AZ: Department of Geoscience, University of Arizona. 37(1): 1-6.

Verano, John W.; Ubelaker, Douglas H., eds. 1992. Disease and demography in the Americas. Washington, DC: Smithsonian Institution Press. 294 p.

Walthall, John A. 1980. Prehistoric Indians of the Southeast: archaeology of Alabama and the Middle South. Tuscaloosa, AL: University of Alabama Press. 299 p.

Ward, H.; Trawick, Davis; Stephen, R.P., Jr. 1999. Time before history, The archaeology of North Carolina. Chapel Hill, NC: University of North Carolina Press. 312 p.

Watts, W.A. 1971. Vegetation history of Georgia and central Florida. Ecology. 52(4): 676–690.

Watts, W.A. 1980. Late-Quaternary vegetation history at White Pond on the inner Coastal Plain of South Carolina. Quaternary Research. 13: 187–199.

Watts, W.A. 1983. Vegetational history of the Eastern United States 25,000 to 10,000 years ago. In: Wright, H.E., Jr.; Porter, Stephen C., eds. The late-quaternary environments of the United States, the late Pleistocene. Minneapolis: University of Minnesota Press: 294-310. Vol. 1.

Webb, S. David. 1981. A cultural resources survey of the Continental Shelf from Cape Hatteras to Key West. Introduction and physical environment. Report ubmitted by Science Applications, Inc. to the Bureau of Land Management. 112 p. Vol. I. [On file with: Wayne D. Carroll, Forest Resources Department, Clemson University, Clemson, SC].

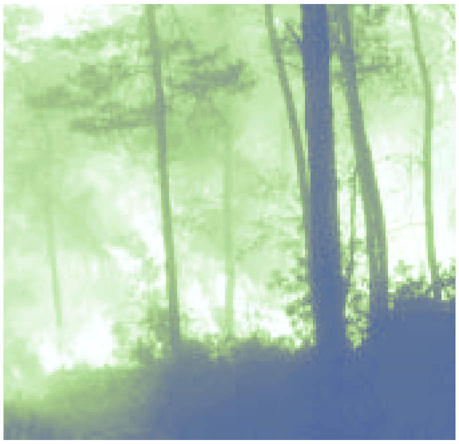
Webb, T., III; Bartlein, P.J.; Kutzbach, J.E. 1987. Climatic change in Eastern North America during the past 18,000 years; comparisons of pollen data with model results. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 447-462. Vol. K-3.

Westhoff, V. 1983. Man's attitude towards vegetation. In: Holzner, W.; Werger, M.J.A.; Ikusima, I., eds. Man's impact on vegetation. The Hague, Netherlands: Dr. W. Junk. 307 p.

Wing, Elizabeth S.; Brown, Antoinette B. 1979. Paleonutrition: method and theory in prehistoric foodways. New York: Academic Press. 202 p.

Wright, H.E., Jr. 1987. Synthesis; land south of the ice sheets. In: Ruddiman, W.F.; Wright, H.E., Jr., eds. The geology of North America, North America and adjacent oceans during the last deglaciation. Boulder, CO: Geological Society of America, Inc.: 479-488. Vol. K-3.

U.S. Department of Agriculture, Forest Service. 1965. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture, Forest Service. 762 p.



Chapter 25: Background Paper: Fire in Southern Forest Landscapes

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Fire as a Landscape Process

Other than land clearing for urban development (Wear and others 1998), no disturbance is more common in southern forests than fire. The pervasive role of fire predates human activity in the South (Komarek 1964, 1974), and humans magnified that role. Repeating patterns of fire behavior lead to recognizable fire regimes, with temporal and spatial dimensions. Understanding these fire regimes is essential to examining the importance of fire in southern landscapes and integrating fire into forest management. This chapter has six sections:

1. Fire regimes and fire types
2. Fire history in the South
3. Fire regimes of southern forests
4. Prescribed fire
5. Smoke management
6. Restoring fire into southern ecosystems

Fire Regimes and Fire Types

Fire Regimes

Fire regime refers to the long-term nature of fire in an ecosystem (Brown 2000), including both frequency and severity of effects. The interval between fires in southern forests may be as short as a year or as long as centuries. The intensity of fire and severity of effects can vary in scale from benign to catastrophic. Because of the spatial and temporal variability of fire and its effects, descriptions of fire regimes are broad (Whelan 1995). The fire regimes used in this chapter follow the descriptions used in Brown and Smith (2000). They include the understory, mixed, and stand replacement fire regimes.

Fires in the understory fire regime generally do not kill the dominant vegetation or substantially change its structure. Approximately 80 percent or more of the aboveground dominant vegetation survives fire (Brown 2000). The understory fire regime occurs primarily in southern pine and oak-hickory forests, which support pine and pine-oak associations such as Kuchler's southern mixed forest, oak-hickory-pine, and oak-hickory associations.

The severity of fire in the mixed fire regime either causes selective mortality in dominant vegetation, depending on tree species' susceptibility to fire, or varies between understory and stand replacement (Brown 2000). The mixed fire regime best represents the resettlement fire history for several hardwood- and conifer-dominated ecosystems. The conifers include pitch pine and Virginia pine of Kuchler's oak-pine association (Kuchler 1964) and pond pine, a dominant tree of the pocosin association. The conifer types fit the mixed fire regime because fire intensities are generally greater than in the understory fire regime and cause mortality ranging from 20 to 80 percent of the overstory. The hardwood ecosystems include mesophytic hardwood, northern hardwood, and elm-ash-cottonwood forest types. Although the hardwoods are prone to fire injury, many survive numerous fires before eventually being girdled. These fires tend to have low intensity because fuels are less flammable than in ecosystems with a substantial conifer component. The low-intensity presettlement fires that wounded or killed many trees did not cause enough mortality (greater than 80 percent) to be considered stand replacement regimes (Wade and others 2000).

In the stand replacement fire regime, fires kill aboveground parts of the dominant vegetation, changing the aboveground structure substantially. Approximately 80 percent or more of the aboveground dominant vegetation is either consumed or dies as a result of fires (Brown 2000). Several vegetation types in the Eastern United States are represented by stand replacement fire regimes, including oak-gum-cypress (bay forests), sand pine, Atlantic white-cedar, and spruce-fir. Table Mountain pine usually is regarded as having a stand replacement fire regime, but a mixed regime may be more accurate as it produces the seedbed conditions needed for survival of seedlings.

Fire Types

Three kinds of fires burn in forests when weather and fuel conditions permit ignition and sustained combustion: surface fire, ground fire, and crown fire. Surface fires burn the upper litter layer and small branches that lie on or near the ground. Surface fires usually move quickly through an area, and do not consume the entire organic layer. Moisture in the organic horizons often prevents ignition of the humus layer, and protects the soil and soil-inhabiting organisms from heat. The heat pulse generated at the burning front of these fast-moving fires does not normally persist long enough to damage tissue beneath the thick bark of large trees. However, it will girdle the root collar of small trees and shrubs, and reduce small-diameter branches and other fine surface fuels.

Ground fires smolder or creep slowly through the litter and humus layers, consuming all or most of the organic cover, and exposing mineral soil or underlying rock. These fires usually occur during periods of protracted drought when the entire soil organic layer may dry sufficiently. They may burn for weeks or months until precipitation extinguishes them or fuel is exhausted.

Crown fires occur when stand structure, weather, and ladder fuels (heavy accumulations of understory material such as slash piles, shrubs, and lower branches of standing trees, often draped with fallen needles) allow surface or ground fires to ignite tree crowns and spread to other crowns. Crown fires occur in forests during periods of drought and low relative humidity, particularly in areas with a dense, volatile understory. Crown fires generate tremendous heat that rises in a strong convection column, drawing in surface winds that fan the flames even more. Heated air blowing across the flames warms and dries the fuel ahead of the fire, and releases volatile gases from vegetation in the path of the flaming front. Crown fires kill all trees and shrubs in their path and consume most of the surface organic layers.

The shorter the interval between fires, the more likely that fires kill only small trees or particularly susceptible species, such as thin-barked hardwoods, resulting in an understory fire regime. This regime usually perpetuates fire-adapted species (Mutch 1970). As fire frequency decreases, fuel accumulates, increasing the probability of a fire intense enough to kill nearly all trees. Fires in forests regenerated by a stand replacement fire regime come at frequencies of 25 to 100 years and probably maintain high levels of diversity in the landscape (Waring and Schlesinger 1985). In the mixed fire regime, either some susceptible overstory species are killed but the stand is not replaced, or fire severity varies between understory and stand-replacing fire.

Fire History of the South

To appreciate the pervasive role of fire in shaping southern forests requires an understanding of the dynamic response of southern ecosystems to climate change since the retreat of the Laurentide Ice Sheet, which began around 18,000 years ago, and the extent of human influence, which likely began about 14,000 years ago. Humans exert an influence by igniting or suppressing fires. Native Americans used fire extensively for thousands of years. The early European settlers continued and to a degree expanded the use of fire. In the last century, however, human influence over fire in the South changed markedly.

We have divided the long history of fire since humans arrived in the South into five periods:

- From the earliest appearance of humans in North America around 14,000 years ago (Fagan 2000) until European contact 500 years ago, the first period was one of increasing human population level and more extensive use of fire.
- For the first 400 years after their arrival, the early European settlers continued to use fire in much the same way as Native Americans, often reoccupying and farming land cleared by Native Americans and expanding burning of woodlands to provide forage for livestock (Williams 1992).
- At the end of the 19th century and extending into the 20th century, the remaining southern forests were extensively logged to support economic expansion; wildfires were common in the slash left behind.
- In reaction to these widespread and destructive wildfires, the fourth period of fire suppression started in the early 1900s.
- The current period is one of fire management, in which the natural role of fire is increasingly recognized and incorporated into forest management.

Use of Fire by Native Americans

The role of fire was dramatically increased with the arrival of aboriginals in America about 14,000 BP (before present). Hunting and gathering characterized their progressively more sophisticated cultures until the advent of settled societies after 3,000 BP in the eastern woodlands (Fagan 2000). Beginning about 6,000 BP (Middle Holocene), warmer climates and final wastage of the Laurentide Ice Sheet (Delcourt and Delcourt 1981, 1983) translated into increased food resources and rapid population growth. By 5,000 BP, sea level had stabilized, and vegetation patterns were essentially as we find them today.

After this rapid population growth, more or less permanent settlements appeared, primarily in river valleys and rich bottomland soils from the Coastal Plain to the mountains (Fagan 2000). After 3,000 BP, population pressures led to cultivation of native plants typical of disturbed habitats. After 1,000 BP, corn cultivation was widespread (Hudson 1982) and bean cultivation by 800 BP (Smith 1994), but hunting and gathering were still prominent activities. Population density was probably greater in the southern than in the northern part of the eastern woodlands and greater on the coast than inland, but higher densities extended inland along major rivers (Driver 1961).

Judging the extent to which forests and other vegetation were influenced by Native American use of fire requires knowledge of the typical pattern of land use and the population levels before European contact (Kemmerer and Lake 2001). Williams (1992, p. 40, fig. 2.8) presented a concept of a typical southern woodland village. Located on a stream or river, the clearing for the village and surrounding fields of mostly corn, beans, and squash extended for 4 miles. Girdling larger trees and burning the undergrowth cleared this area originally, and burning kept it open, in much the way that swidden agriculture occurs in the tropics today. The field zone was buffered by a further 1.25-mile-wide zone that was burned annually for defense (visibility), where fuel wood and berry gathering took place. Another 1- to 2.5-mile-wide zone was burned frequently for small game and foraging. This entire disturbance complex was surrounded by closed forest. Nearby was a large zone kept in open grassland by burning for large game animals. Except in river floodplains, this village complex had to be moved periodically as soil fertility was reduced in the continuously cropped fields and as nearby fuel wood was exhausted. To maintain proximity to open grassland for hunting, successive village sites were probably within 6 to 25 miles of each other.

Pyne (1997) described the careful use of fire by Native Americans. Cereal grasses were fired annually, basket grasses and nut trees every 3 years, and the grassy savanna hunting areas annually. Brush and undergrowth in forests were burned for visibility and game every 7 to 10 years. Fire also was used to drive and surround game (Hudson 1982) and reduce the threat of wildfires, especially along the coast, where pines dominated and lightning provided an ignition source. Even in areas of the Southern Appalachian Mountains that were sparsely settled and not prime hunting ground, major trails that followed rivers were kept open by burning, and escaped campfires probably caused large areas to burn.

The preponderance of anecdotal (Stewart 1963, Williams 1992), archeological (Dobyns 1966, 1983; Jacobs 1974), ecological (Delcourt and Delcourt 1997, 1998; Hamel and Buckner 1998), and meteorological evidence supports the conclusion that fire was a widespread occurrence in the pre-European landscape. The full extent of Native American impact, however, hinges on estimates of population levels. Until recently, it was thought that the earliest estimates, made after European settlement, represented precontact levels, and Native American populations declined only after sustained exposure to European diseases. A contrasting view, first presented by Dobyns (1983) but built on earlier work, assumed diseases were spread even without direct physical contact between Europeans and Native Americans. Thus, even the earliest census estimates reflected populations already decimated by disease, by as much as 95 percent. Dobyns (1983) estimated North American populations as high as 18 million at the beginning of the 16th century, in contrast to previously accepted estimates of less than 1 million (Fagan 2000). Archeological evidence in the Lower Mississippi River Valley was used by Ramenovsky (1987) to test contrasting hypotheses of how diseases spread and their effect on Native American populations. She found evidence of widespread declines during the 16th century, after the DeSoto expedition (1538–41) and before French settlement began in the late 17th century. Generally accepted estimates of population levels are more conservatively placed at between 9.8 million and 12.25 million for North America (Fagan 2000, Ramenovsky 1987, Williams 1992).

Estimates of the cleared land needed to support a person range from 0.33 acres (2.3 acres when fallowing is taken into account) to 30 to 40 acres for all cleared and burned land (Williams 1992). For argument's sake, we can assume that half the population of 12 million was part of the eastern woodland culture involved in the sedentary lifestyle described above, and that each person represented 10 to 20 burned acres. The 60 million to 120 million acres thus estimated to be affected by clearing and burning would constitute 22 to 44 percent of the cropland acreage presently farmed in the 31 Eastern States (Williams 1992). The point is not to accept the size of the number but to appreciate the magnitude of Native American impact on the landscape through the use of fire.

Use of Fire by Early European Settlers

Initial European agriculture differed little from that of Native Americans, but it rapidly became more extensive (Williams 1992). Spreading from the coast inland along rivers, the early settlers sought out Native American clearings for their farms or used similar techniques of girdling and burning to clear land. Instead of using the Native American system of rotational clearing (swidden agriculture), however, Europeans maintained extensive permanent fields. Burning was extended to the bottomlands and hilltops to support open grazing, particularly of hogs (Williams 1992). Prior to the Civil War, over 75 percent of the white population of the South was comprised of pastoral herders of Celtic origin (McWhiney 1988, Owsley 1945) who came from the British Isles, Spain, and France where fire had been an integral part of their livelihood.

In time, agricultural practices differed between the coast and the uplands. Small farmers and herders, who originated in the mid-Atlantic colonies, settled the mountains, Interior Highlands, and plateaus. They moved down the Appalachian valleys to settle western Virginia, eastern North Carolina, Tennessee, and Kentucky (Williams 1992). These small farmers adapted Native American cropping practices. Along the coast, large-scale plantations grew market crops, particularly tobacco, rice, and cotton. Before the American Revolution, rice cultivation was limited to inland swamps with minimal impact on coastal forests. Later, a new cultivation technique was introduced, probably by African slaves, which used tidal action to flood rice fields along rivers. This tidal irrigation affected forest lands as far as 35 miles inland (Edgar 1998).

After Coastal Plain soils were exhausted, plantation culture was extended into the Piedmont of Virginia, the Carolinas, Georgia, and the rich bottomlands of the Lower Mississippi Alluvial Valley. On the Coastal Plain, the extensive pine forests away from the rivers were exploited for naval stores. These woodlands were burned periodically, and grasslands were kept open by annual burning. These vast areas between major river valleys hosted large herds of feral and semidomesticated hogs and cattle, tended by prototypical cowboys (McWhiney 1988, Williams 1992).

Early settlers used fire in several ways. They sought out old fields and openings cleared by Native Americans and kept them open by plowing or periodic burning. Woodlands were burned for pasture. Burning small trees and shrubs and girdling large trees cleared new fields. Even though the practice was ineffective, woods in the Piedmont were burned to control the boll weevil, a pest of cotton (Dorn and Derks 1988). As settlers began moving into the mountains, they first settled the better land along the major streams. A description of the settlement of Mulky Creek in the north Georgia mountains tells of harvesting a first hay crop beneath the open timber on a south slope (Brender and Merrick 1950), where broom sedge grew shoulder high on drier sites and wild legumes were abundant. Fire must have played a major role in maintaining such an open ecosystem, even before grazing of livestock became a supporting factor (Van Lear and

Waldrop 1989). Annual burning became a standard practice wherever grazing animals were kept, even in the more remote mountain regions.

Fire Following Exploitive Logging

Lumbering was always a component of rural life in the South, but until the late 19th century it was a secondary activity to farming (Williams 1992). Lumbering activity increased after the Civil War to satisfy the needs of rapid industrialization. Between 1880 and 1920, annual lumber production rose in the South from 1.6 billion board feet to 15.4 billion board feet (Williams 1992). Much of the production was from the southern pinery on the Coastal Plain, but virgin stands of baldcypress and bottomland hardwoods were also cleared. The remainder of the "original" southern pine (longleaf) forest was heavily cutover, and then indiscriminately burned every spring to promote forage for free-ranging cattle (Stoddard 1962). These fires eliminated all pine regeneration except for grass-stage longleaf. Regeneration of even longleaf pine was effectively prohibited by the widespread clearing that eliminated sources of seed and by feral pigs that uprooted any seedlings that did get established (Frost 1993). By 1920, there was an estimated 90 million acres of cutover, unproductive land in the South (Williams 1992).

During the late 1800s, timber companies began buying large tracts of land in the more remote sections of the Southern Appalachians (Van Lear and Waldrop 1989). Slash often was burned after logging and then the land was grazed. In much of the Southern Appalachians, the combined effects of grazing and burning effectively prevented the reestablishment of woody vegetation (Brender and Merrick 1950). Even the pines could not reproduce under a regime of annual fire.

An Era of Fire Suppression

Suppressing all fire was seen as the only way to reforest the cutover land (Pyne 1997, Williams 1992). Rangeland users, however, were opposed to fire prevention, and arson was commonplace (U.S. Department of Agriculture 1988). The turning point was passage of the Clarke-McNary Act of 1924, which provided Federal funding for State fire-control efforts. Federal funding rapidly grew from $5 million in 1930, to a high of $18 million in the 1960s. State funding grew from nearly $10 million in 1930 to over $90 million in the 1980s (U.S. Department of Agriculture, Forest Service 1988). In 1930, 70 million acres were protected from fire; by 1980, over 233 million acres were protected (U.S. Department of Agriculture, Forest Service 1988). In 1930, about 2 million acres of timberland burned. By 1983, the area burned by wildfire dropped to 279,000 acres. During World War II, fire control became more difficult because personnel were diverted to the war effort. Nevertheless, prevention of smoke around airfields and fires near the coast, where they would make ships visible to submarines, became military necessities. The first approval for prescribed fire in southern national forests was on the Osceola National Forest in Florida. A prescribed fire was approved in 1943 because the forest could not muster fire suppression crews.

The rising value of pine pulpwood also helped fire control efforts. Pulp and paper companies invested heavily in manufacturing plants and wanted to protect their investments. They provided political support for increasing public expenditures for fire suppression on private as well as public land. A rise in public land ownership brought the Forest Service and National Park Service into suppression efforts. In the 1920s, the Forest Service was opposed to the use of fire in forests, and even light burning was prohibited on the recently established national forests (Demmon 1929, Schiff 1962). Earlier leaders of the Agency, however, recognized that fire exclusion led to another set of problems and advocated the use of prescribed burning under southern pines to reduce hazards (Eldredge 1911, Graves 1910, Pinchot 1899).

The Era of Fire Management

Native Americans and early European settlers practiced prescribed burning, where fire is set intentionally to manage vegetation and reduce the risk of wildfire. It became commonplace in southern forest management after World War II. The unrealistic goal of excluding fire from southern forests was abandoned, in the face of experience and research by Forest Service and university scientists (U.S. Department of Agriculture, Forest Service 1988). Prescribed fire was advocated in the management of longleaf pine and bobwhite quail (for a synopsis, see Wade and others 2000). The role of prescribed fire in reducing the hazards of disastrous wildfires was realized after major fires in the South during the droughts in the 1930s and 1950s. With the advent of fencing laws and the end of open range, the incentive for general burning to stimulate forage was reduced (U.S. Department of Agriculture, Forest Service 1988).

Southern resource managers burn an estimated 8 million acres annually of forest, range, and cropland for many objectives but mostly for hazard reduction, wildlife habitat improvement, and range management (Wade and others 2000). An increasing number of acres are burned each year for ecosystem restoration and maintenance. In spite of this level of prescribed burning, wildfires are common in the South. Most fires are human-caused in all Southern States, with arson playing a variable role, depending upon the State and region within a State. Wildfires are relatively common in the Southern Appalachian Mountains. The majority of wildfires on Federal land (88 percent) are human-caused, due either to carelessness or arson. The small proportion (12 percent) caused by lightning is restricted to ridgetops (Southern Appalachian Man and the Biosphere 1996).

Fire Regimes of Southern Forests

The climate of the South is characterized by long, hot growing seasons; abundant rain punctuated by occasional multiyear droughts; and the most frequent wind (Cry 1965) and lightning (Komarek 1964) storms in North America (Muller and Grimes 1998). Lightning becomes increasingly common as one moves from north to south. Natural disturbances such as microbursts, tornadoes, and hurricanes can have major impacts on forest structure (Peterson 2000) and the distribution of fuels, and set the stage for intense fires (Myers and Van Lear 1997).

Before Native Americans arrived, fire occurred mainly in the spring and summer thunderstorm season, ignited by lightning (Robbins and Meyers 1992). Most fires were probably limited in extent, as normally humid and still nighttime conditions in the summer tend to extinguish fires in light fuels. Some fires, however, were undoubtedly far ranging because they were associated with dry weather fronts (Wade and others 2000). Native Americans burned many sites frequently, limiting fuel buildup. They also extended the burning season, setting fires throughout the year, and often several times each year (Martin and Sapsis 1992). Periodic high-intensity wind-driven fires or severe-drought fires together with chronic lightning and Native American fires created the open woodlands, numerous smoke columns, and extensive smoke and haze referred to by early European explorers (Barden 1997, Landers and others 1990, Olson 1996).

In explaining the climate and vegetation interactions that influence fire regimes in southern forests, we refer to four broad physiographic regions (Martin and Boyce 1993): (1) the Coastal Plain (Atlantic and Gulf coasts, including peninsular Florida and the Lower Mississippi Alluvial Valley); (2) the Piedmont; the Southern Appalachians (including Appalachian plateaus and mountain ranges); (3) and the Interior Highlands (including the Interior Low Plateaus of Kentucky and Tennessee and the Ozark-Ouachita Highlands). Occurrences and frequencies of fire regimes for specific plant communities before European settlement are shown in table 25.1.

Table 25.1—Occurrence and frequency of presettlement fire regime types by SAF cover types

Fire regime types	Understory fire regime	Mixed fire regime	Stand replacement fire regime
		Frequency (years)	
Vegetation community			
Longleaf pine	1 to 4		
Slash pine	1 to 4		
Loblolly pine	1 to 4		
Shortleaf pine	2 to 15		
Oak-hickory	<35		
Pond pine		6 to 25	
Pitch and Virginia pines		10 to 35	
Table Mountain pine		<200	
Mixed mesophytic		10 to 35 or >200	
Bottomland hardwoods		<200	
Sand pine			25 to 60
Bay forests			20 to 100
Atlantic white cedar			35 to 200
Northern hardwoods			300 to 500

SAF = Society of American Foresters.
Source: Modified from table 4-1 in Wade and others (2000).

Fire-adapted plant communities span the full elevational gradient from saltwater marshes to mountain balds (Wade and others 2000). The extent of these communities at the time of European colonization is difficult to reconstruct because much of this region was cleared and plowed at least once, or logged to support the industrial revolution. An estimated 80 percent of the Coastal Plain was cleared, with some counties reaching near 100 percent (Brender 1974, Nelson 1957). Hamel and Buckner (1998) described the "original southern forest" at three time periods: (1) late glacial times, following retreat of the Laurentide Ice Sheet, but after aboriginal immigration; (2) prior to European contact in 1492; and (3) after the first permanent English settlement in 1607. They concluded that no specific time period represents the "true" original condition of the southern forest because it has been responding to climate change and has been shaped by humans for millennia. Even communities that escaped logging or clearing in the last 200 years have undergone dramatic changes because of decades of fire exclusion.

Coastal Plain Region

Coastal Plain forests in the South are predominantly pine in the uplands and hardwoods in the floodplains of major and minor rivers. Before European settlement, fire in virtually all forest types in the Coastal Plain had a return interval of less than 13 years (Frost 1998). Frequent light ground fires characterized most Coastal Plain ecosystems dominated by longleaf, slash, and loblolly pines (Wade and others 2000). Blowdowns and drought led to occasional severe fires (Myers and Van Lear 1997). Explosive increases in southern pine beetle (*Ips* spp. and *Dendroctonus frontalis*) populations and subsequent pine mortality often either preceded or followed these fires. Occasional severe fires in depressional wetlands typically cause stand replacement (Wade and others 2000).

The dominant species of Coastal Plain pine forests—longleaf, loblolly, slash, pond, sand, and shortleaf pines—differ in their tolerance of fire, requirements for soil aeration, and ability to withstand drought. In the following sections, we describe the fire regimes of forests dominated by these pine species, in addition to other forest types.

Longleaf pine—Open pine forests, woodlands, and savannas distinguish the longleaf pine ecosystem. Longleaf pine tolerates a wide range of sites from wet, boggy flatwoods underlain with tight clays across xeric, deep sands to thin stony soils on south-facing mountain slopes (Ware and others 1993). On infertile sites, surface soils are typically acidic, tend to dry quickly after precipitation, and are characterized by a lack of organic matter and low fertility (Landers and Wade 1994). Longleaf pine also occupied a significant area of fertile soils where frequent fires gave it the advantage over loblolly pine and hardwoods. These fertile sites were cleared for agriculture. Examples of longleaf on fertile soils persist in the red hills region of Georgia and at Fort Bragg, NC. Many soils in the Gulf Coastal Plain also tend to be more fertile than the infertile sands often associated with longleaf pine. Longleaf pine ecosystems persist and maintain their diversity because of constant disturbance (Christensen 1993, Landers and Wade 1994, Landers and others 1995, Wells and Shunk 1931), and recurrent fire is crucial to perpetuation of these ecosystems (Andrews 1917).

Typical longleaf pine sites burned every 1 to 4 years prior to the arrival of Europeans, and then every 1 to 3 years until aggressive fire suppression activities began in the 1920s and 1930s (Landers 1991, Landers and others 1990). Fire frequency decreases as typical upland sites grade toward very wet sites where ignition is inhibited or very dry sites with low rates of fuel accumulation.

Longleaf pine has numerous traits adapted to recurrent understory fires. It goes through a grass stage of limited aboveground growth while an extensive root system is developed. Coming out of the grass stage, a growth spurt (called bolting) quickly gets the terminal buds above the height of the flames. The large buds of longleaf pine are protected from high temperatures by an encompassing sheaf of long needles. Stem bark rapidly thickens, protecting the seedling from light surface fires during the first year of height growth.

If the fire regime is disrupted, such as by suppression activity, longleaf stands are invaded by hardwoods such as sweetgum, oaks, hickories, common persimmon, and southern magnolia (Daubenmire 1990, Gilliam and Platt 1999). These hardwoods form a midstory that prevents the shade-intolerant longleaf pine from regenerating. Many of these hardwoods are somewhat resistant to low-intensity fires when mature (Blaisdell and others 1974), and rootstocks of even understory trees are able to withstand all but annual growing-season fires (Glitzenstein and others 1995, Waldrop and others 1987). Invasive exotics such as cogongrass (Lippincott 1997), Japanese climbing fern, and melaleuca (Wade 1981, Wade and others 1980) are promoted by fire. They create serious problems for those who are trying to restore longleaf ecosystems.

Remnant populations of longleaf pine are also found in the Piedmont and Appalachian Highland (both Blue Ridge and Ridge and Valley) physiographic Provinces of Alabama and Georgia (Boyer 1990, Wahlenberg 1946).

Slash pine—Slash pine is the chief conifer associate of longleaf pine on wet Coastal Plain sites throughout its natural range, from South Carolina to Louisiana (Lohrey and Kossuth 1990). Slash pine seedlings are susceptible to fire, thus confining it historically to wet sites (Monk 1968). Slash pine has successfully invaded many drier sites after exploitive logging and fire suppression removed longleaf pine and disrupted fire regimes. The most hydric slash pine sites are depressions such as bays, bayheads, titi swamps, and cypress pond margins embedded within the flatwoods matrix. On such sites, slash pine generally develops a pronounced buttress (comprised mostly of bark) that protects the tree from heat girdling during drought fires.

Loblolly pine—Loblolly pine historically occurred on wet sites similar to those occupied by slash pine, and for the same reason—its susceptibility to fire when young. With increased fire suppression, loblolly pine dominance dramatically increased as it seeded into former longleaf pine sites and abandoned agricultural fields. Loblolly pine was planted even more extensively than slash pine. It is currently the leading commercial tree in the Southern United States, comprising more than half of the standing pine volume in the region (Baker and Langdon 1990).

Loblolly pine is also common along stream bottoms in the Piedmont where fire-free intervals historically exceeded 5 to 6 years (Wade and others 2000).

Pond pine—Some pocosins (depressional wetlands) with a mixed fire regime are dominated by pond pine (Wade and others 2000). Most pocosins burn on a 20- to 50-year cycle (Christensen and others 1988), but on better sites fire-return intervals of 3 to 10 years can result in pine savanna with a grass understory. These wet sites have a rank shrub layer comprised of many ericaceous evergreen shrubs that tend to burn intensely, resulting in the topkill or death of all vegetation except pond pine. Pond pine has the ability to resprout from its base as well as along its stem and branches (Wenger 1958); thus, its aboveground stem survives higher intensity fires than stems of other pine species. This trait allows the species to dominate wet areas such as pocosins, which support intense fires. Summer fires during severe droughts usually eliminate the pond pine as well, because the underlying organic soil burns, destroying root systems.

Sand pine—Sand pine has a stand replacement fire regime, but its two varieties, Choctawhatchee and Ocala, require different fire management because one (Ocala) has serotinous cones and the other does not (Wade and others 2000). The historic fire frequency for the Choctawhatchee variety is unknown, but lightning fires were rare where it occurs. This variety grows in pure stands, directly inland from the beach, separated from more fire-prone vegetation types by wet intradune swales and sparse dune vegetation. Hurricanes were likely a frequent disturbance and probably more responsible than fire for stand replacement. Both varieties are thin-barked and easily killed by fire. The fire cycle for Ocala sand pine corresponds roughly to stand longevity, which is 30 to 60 years (Christensen 1981). Sand pine needles are short and tend to form a flat mat on the forest floor that does not burn well, but it will support creeping fires. The Ocala variety recaptures the site after fire from seed from the freshly opened serotinous cones. Although Ocala sand pine can be regenerated using prescribed fire, this must be a stand replacement fire. Such fires are useful only for management of wilderness or natural areas where timber production is not an objective.

Bay forests—This general type is characterized by a stand replacement fire regime (Wade and others 2000). Carolina bays and pocosins without a pine or Atlantic white-cedar overstory are the major vegetation types. Many stands contained a merchantable overstory that has been harvested, thereby altering the fire cycle. They are all characterized by a dense tangle of evergreen and deciduous shrubs and vines (Richardson and Gibbons 1993). Numerous species of special concern, including several Federal- and State-listed species, occur in this vegetation type. This type now burns on about a 20- to 100-year cycle, but uncertainty exists about the historic fire frequency (McKevlin 1996, Wharton 1977). Shrub bogs are bay forests that burn every 2 to 5 decades (Christensen 1977). More frequent burning, at least once a decade, removes the shrub layer, resulting in an herb bog. If the underlying organic soils are completely consumed, both pocosins and bays will revert to marsh (Richardson and Gibbons 1993).

Atlantic white-cedar—Before European settlers harvested this prized species, it was generally perpetuated by major disturbances, probably stand-replacing crown fires (Wade and others 2000). It is a prolific seeder, beginning at an early age (as young as 3 years). The seed, released in the fall, is stored in the forest floor. Under normal (wet) conditions, crown fires destroy the aboveground vegetation. Fires during droughts consume the forest floor and stored seed. Two fires in close succession (before the seed bank is replenished) will create an herb bog, shrub bog, or bay forest, depending upon the future fire return interval.

Bottomland hardwoods—The historical role of fire in the bottomland hardwood ecosystem is unclear (Wade and others 2000). Drought probably played a role, and low- to moderate-intensity wildfires may have been frequent (Lentz 1931, Toole and McKnight 1956). Low-intensity fires are the norm in these forests because fuel loads are generally light (except after damaging wind and ice storms) due to rapid decomposition on these moist, humid sites. In canebrakes, fire intensity is much higher, but fire severity is low except during drought. Large fires can only occur after extended drought, usually when a dry fall is followed by a dry spring.

Other community types—Embedded within pine and floodplain ecosystems were numerous other ecosystems such as depressional wetlands, including Carolina bays, lime sinks, cypress ponds and savannas, gum ponds, bay swamps, pitcher plant bogs, shrub bogs, and spring seeps (Stanturf and Schoenholtz 1998). During prolonged dry periods, fire can enter these wetlands from adjacent upland communities (Kirkman and others 1998, Wharton 1977). When rainfall is more normal, periodic fire keeps hardwoods from invading and capturing upland sites (Barrett and Downs 1943, Chaiken 1949, Harcombe and others 1993, Heyward 1939, Oosting 1942, Platt and Schwartz 1990, Wahlenberg 1949, Wells 1928). As the interval between fires increases, the hardwood midstory also increases in height and leaf area, shading out herbaceous groundcover. When the continuity of the herbaceous understory is broken up and its ability to spread fire is reduced, the hardwoods expand until they eventually dominate the site.

Piedmont Region

The Piedmont region is a transition topographically and ecologically between the Coastal Plain and the Appalachian Mountains. Pine and hardwood species from these adjacent regions overlap in the Piedmont, often occurring together in mixed pine-hardwood stands. Fire behavior may differ considerably between these regions, however, even in plantations, because of very different understory species assemblages. Nevertheless, fire regimes are similar, depending upon site and stand conditions, particularly the amount of pine versus hardwood in a stand. The following discussion focuses on shortleaf pine, which is more widespread in the Piedmont and mountains than in the Coastal Plain.

Shortleaf pine—Shortleaf pine has the widest range of any of the eastern pines and is found throughout the Piedmont, mountains, and Interior Highlands, as well as the Coastal Plain. Shortleaf pine has an understory fire regime (Wade and others 2000). It occupies a wide variety of soils under many environmental conditions but will not tolerate poor drainage. Shortleaf pine is a prolific seeder but requires a mineral soil seedbed. Loblolly pine is the chief associate of shortleaf pine at lower elevations throughout the Midsouth and Southeast. Loblolly pine dominates the heavier, moist soils while shortleaf pine dominates the lighter, drier soils. Loblolly drops out at about 400 feet elevation in the Ozarks and Ouachitas, resulting in pure stands of shortleaf pine up to about 2,000 feet on south-facing slopes. Above 2,000 feet, hardwoods begin to dominate with shortleaf pine disappearing at about 3,000 feet. In the Appalachians and upper Piedmont, Virginia pine replaces shortleaf pine on drier, nutrient-poor sites east of the Appalachian divide.

The historic shortleaf pine fire return interval is thought to have ranged from about 2 to 6 years on fertile, lower elevation sites. It extended to 6 to 15 years on drier, nutrient-poor sites where fuels take longer to accumulate. Annual burning was common throughout the shortleaf pine region after European settlement (Matoon 1915).

Ability to resprout, abundant seed crops, rapid juvenile growth (especially of sprouts), and a low resin content of the wood make this species markedly tolerant of fire (Mattoon 1915). Shortleaf pine forms dense sapling stands that are favored over competing hardwoods by frequent fire. Shortleaf pine can repeatedly sprout from the base if the tree is topkilled, at least until trees are 15 to 30 years old (Matoon 1915, Wakeley 1954). Trees larger in diameter at breast height than 0.5 inches are somewhat resistant to fire, and mortality is negligible once trees reach 4 inches in diameter at breast height (Walker and Wiant 1966). Like other southern pines, trees over 5 feet tall rarely die when crown scorch is less than 70 percent and buds are not killed when foliage is consumed.

Mountains and Interior Highlands Regions

Fire played a major role in shaping vegetation communities in the Appalachian Mountains. Overstories of southern yellow pines (Virginia, shortleaf, pitch, and Table Mountain) typically dominate south- and west-facing slopes (Whittaker 1956), but in the absence of hot fires at rather frequent intervals, hardwoods will succeed pines. Table Mountain pine is well adapted to fire because of its serotinous cones. Although these can open without fire, many remain closed and ensure a supply of seed regardless of the time of year when a fire occurs (Barden 1977). This adaptation allows Table Mountain pine to cast seeds when seeds of other pine species would be destroyed. Serotinous cones have also been observed in pitch pine and rarely in Virginia pine, but this character is not well documented. Shortleaf and pitch pines can sprout from the root collar after topkill by fire. Fires of human origin probably perpetuated pine in the Appalachians since lightning fires did not occur frequently enough or were not intense enough to maintain pines on these xeric sites (Whittaker 1956). Fire protection in recent decades has allowed hardwoods to dominate on sites where pines once thrived.

Oak-hickory forests—The oak-hickory forest type (Barrett 1994, Braun 1950) occurs primarily on average to dry upland sites, but it also can be found on moist upland sites, depending upon past disturbance history. The oak-hickory type historically had an understory fire regime (Brose and others 2001, Van Lear and Waldrop 1989, Wade and others 2000), but presettlement fire frequencies are not known. Conservative estimates from dendrochronological studies suggest fire return intervals of 2.8 years (Cutter and Guyette 1994) to 14 years (Buell and others 1954, Guyette and Dey 1997). The frequency and extent of Native American burning decreased substantially after European contact. As a result, forest canopies closed over previously open grasslands, savannas, and woodlands (Buckner 1983; Denevan 1992; Dobyns 1983; MacCleery 1993, 1995; Pyne 1997). European settlers of oak-hickory forests increased the frequency and extent of burning and shortened fire-return intervals to 2 to 10 years; they burned many sites annually (Cutter and Guyette 1994, Guyette and Dey 1997, Holmes 1911, Sutherland 1997, Sutherland and others 1995).

Presently, infrequent low-intensity surface fires during the spring and fall characterize the fire regime of oak-hickory forests. These fires are caused almost exclusively by humans and burn small areas (Barden and Woods 1974, Pyne and others 1996, Ruffner and Abrams 1998). Fire exclusion created a fuel complex that is probably very difficult to ignite. On drier mountainous sites, fire exclusion allows ericaceous shrubs such as mountain laurel and rhododendron to move from riparian areas into upland forests (Elliott and others 1999). These shrubs are shade tolerant and evergreen, shading the forest floor throughout the year. Although the forest floor rarely dries enough to support surface fire, the ericaceous shrub layer is flammable. When it burns, it typically supports intense crown fires.

Mixed mesophytic hardwoods—The hardwood forests of the Appalachian and Ozark Mountains and the upland hardwoods of the Coastal Plain and Piedmont have been grazed and burned regularly from the time of earliest settlement (Van Lear and Waldrop 1989). In the absence of fire, a mixed mesophytic forest develops. Although little is known about presettlement fire, it appears that fire was much more common in the mesophytic forests west of the Appalachian divide than in those to the east (Harmon 1984).

Table Mountain pine—Prehistoric fire regimes are unknown, but the presence of serotinous cones suggests that Table Mountain pine is adapted to stand replacement fires (Wade and others 2000). However, some stands are known to regenerate successfully without fire (Barden 1977, Williams and Johnson 1992), and crown fires can create seedbed conditions too xeric for optimum survival (Waldrop and Brose 1999). The historic fire regime for Table Mountain pine stands is probably best described as mixed. Native Americans exposed both Table Mountain pine and pitch pine to frequent understory burns, keeping these stands fairly open. Stand replacement fires probably occurred only when Native Americans were not living in a particular location and fuel loads became heavy. Fires in Table Mountain pine were more frequent, more intense, and probably larger earlier this century (Barden and Woods 1974). Evidence from existing stands supports this mixed fire regime. Table Mountain and pitch pines occur as uneven-aged stands throughout the Southern Appalachians, with most trees ranging from 50 years to over 200 years old (Brose and others 2002, Sutherland and others 1995). Abundant mountain laurel in the same stands is younger than 50 years old, suggesting that frequent low-intensity fires created and maintained these uneven-aged stands until the 1950s. Fire exclusion since the 1950s allowed mountain laurel to establish and create understory conditions that prevented the pines from regenerating.

Pitch and Virginia pines—Mixed severity fires were probably prevalent over much of the range of pitch and Virginia pines. Native American burning maintained pitch pine as an understory fire regime type, with a 2- to 10-year fire interval (Wade and others 2000). This frequency maintained stands with relatively large pines, scattered smaller pines and oaks, and sparse understory besides low ericaceous shrubs and herbs (Little 1946, 1973). The historical fire regime in Virginia pine is unknown but was probably less frequent and resulted in higher mortality. Today, there is a mixed fire regime with long fire-return intervals. The majority of wildfires occur during the growing season when damage is greater.

Southern forest types with long fire-return intervals—Only three vegetation types in southern forests typically have long fire-return intervals: mangroves, high elevation spruce-fir, and northern hardwoods. Surface and ground fires are precluded from mangroves because of their location in tidal zones, but lightning may influence stand dynamics and crown fires can enter after severe freezes that occur every few decades (Wade and others 1980). Spruce-fir forests, which occur from the Southern Appalachians northward, burn only after periodic spruce budworm epidemics, probably on the order of centuries (Wade and others 2000). Northern hardwoods occur only on north-facing slopes and deep coves in the South; return intervals there are on the order of millennia (Lorimer 1977).

Prescribed Fire

It is paradoxical that while so much effort is devoted to suppressing wildfires, controlled fire is used extensively in the South to manage forests. By reducing fuel loads with prescribed burning, the risk of catastrophic wildfire is reduced. The history of fire in the South during the last century, as distinct from other regions of the country, reflects the process of coming to terms with this paradox (Pyne 1997).

Prescribed burning is used to attain several objectives: (1) reducing fuel loads and the risk of wildfire (hazard reduction); (2) preparing sites for seeding or planting; (3) controlling understory vegetation in order to regenerate desirable species; (4) benefiting wildlife; (5) controlling insects and diseases; (6) enhancing appearances; (7) improving access; (8) protecting threatened and endangered species; (9) perpetuating (or restoring) fire-dependent species; and (10) improving forage for grazing (Wade and Lunsford 1989). Prescribed burning is most common in Coastal Plain pine forests and in the Piedmont. It is used to a lesser extent in mountain forests, but use will increase as historic fire regimes are reintroduced into natural stands.

Prescribed burning is used less in the Southern Appalachian Mountains than in other areas of the South. Fire behavior is less predictable due to highly variable topography, and the benefits of burning in hardwoods are not well documented (Van Lear and Waldrop 1989). Interest in prescribed fire in hardwoods is increasing, however, as the need to control accumulations of explosive fuels such as mountain laurel and rhododendron becomes recognized (Van Lear and Waldrop 1989). Fire plays a role in community dynamics of several forest types in the Southern Appalachians, indicating a potential role for prescribed burning in their restoration (Brose and others 2001, Southern Appalachian Man and the Biosphere 1996). These community types include mixed mesophytic hardwoods on lower slopes, northern hardwood-hemlock types on north and east slopes, pine-oak mixtures on south to west slopes, and yellow pine dominated communities on ridges and upper slopes with south and west aspects.

Types of Prescribed Fires

Prescribed fires are generally one of three types: head fires, backing fires, or flanking fires. Head fires burn with the wind or upslope. They are of relatively high intensity and move through fuels at a relatively high rate of speed. Head fires are often ignited in strips (called strip head fires) to speed the burning process and to provide the desired intensity. Fire intensity increases as the rear of a previously ignited strip merges with the advancing front of a subsequent strip (Brown and Davis 1973). Backing fires back into the wind or burn downslope. They burn with lower flame heights and lower intensity, and move through the stand at slower speed than head fires. Because of their lower intensity and slower speeds, backing fires are more easily controlled. Flanking fires are set moving parallel to and into the wind. They are generally used to supplement other burning techniques. For example, flanking fires can be used to speed the process of burning with backing fires. Flanking fires are set perpendicular to backfires. Where flanking fires merge, fire intensity increases, but not as much as it does with strip head fires.

The choice of which fire to use depends upon objectives, fuel and moisture conditions, and need to manage smoke. To understand fire behavior and fire effects, the difference between fire intensity and severity should be appreciated. Fire severity describes the condition of the ground surface after burning (Wells and others 1979), whereas fire intensity is the rate at which an ongoing fire produces thermal energy. Although an intense fire usually has severe effects, such congruence is not always the case. For example, any fire that consumes the entire organic layer and alters mineral soil structure and color would be classified as a "severe burn." A high-intensity fire in heavy fuels when the soil and forest floor are moist, however, would leave a large amount of residual forest floor and would not alter soil structure and color. Thus, the severity of such a high-intensity fire would be classified as "light."

Fire effects are related to intensity and duration of exposure. Fire line intensity is the heat output of a unit length of fire front per unit of time (Deeming and others 1977). Fire line intensity is directly related to flame height, which influences fire effects. As trees grow taller and their bark thickens, resistance to fire increases because crowns are higher above the heat of the flames and thicker bark insulates their cambium. The duration of exposure (residence time) also is an important consideration in prescribed fire. Living tissue can be instantly killed at a temperature of 147 °F; it also can be killed by prolonged exposure to lower temperatures (Hare 1965, Nelson 1952). Backing fires of low intensity can be lethal to small stems because the slow speed of the burning front enables lethal cambium temperatures to be reached just aboveground.

Leaf litter is the primary fuel that sustains fire. Loading and thickness of the litter layer vary depending on site, stand age, and season (Albrecht and Mattson 1977, Blow 1955, Crosby and Loomis 1974, Kucera 1952, Loomis 1975, Metz 1954). Fuel weights in like stands on comparable sites vary little longitudinally, but increase northward because decreasing mean temperatures slow decomposition. Most hardwood stands have a litter loading from 1 to 4 tons per acre and a depth of 1 to 5 inches, depending on season. Litter loading and depth are greatest immediately after leaf fall in the autumn and decline until the following autumn. Hardwood leaves in general tend to cup and hold water after a rain, but the leaves of some species of oak tend to curl and dry quickly in comparison to other hardwoods, allowing fire to run through oak litter when other hardwood fuel types are too wet to burn.

Under mature southern pine stands on the Atlantic Coastal Plain, forest floor fuel loads range from about 1.5 tons per acre under an annual dormant-season fire regime to 13 tons per acre after 40 years without a fire. Live groundcover and understory fuels with a ground line diameter less than 1 inch range from about 0.75 tons per acre with annual burns to over 11 tons per acre after 25 years. On Piedmont sites, roughly the same trends hold. Fuel weights are highest in loblolly and longleaf pine stands and appreciably lighter under shortleaf and Virginia pine stands. Shortleaf and mixed shortleaf pine-hardwood stands in the mountains may have substantially heavier fuel loads than similar stands in the Piedmont, at least in part because of a heavier understory component (Albrecht and Mattson 1977). Small woody fuels can be abundant in young stands originating after a major disturbance. Woody fuels are less abundant in midsuccessional and mature stands, but increase in old-growth stands due to accumulation of large downed or standing dead woody material. When present, ericaceous shrubs such as mountain laurel and rhododendron can burn with extreme fire behavior resulting in a mixed severity or stand replacement fire (Waldrop and Brose 1999). Many of the firefighter fatalities in hardwood forests have occurred because of the explosive nature of these fuels.

Resource managers generally prescribe burning conditions that limit fuel consumption to 1 to 3 tons per acre during passage of the flame front. Residual smoldering combustion can more than double these values, especially under drought conditions, or 5 to 6 years after a major disturbance when large downed woody fuels become partially decomposed. More detailed descriptions of fuels and fire behavior can be found elsewhere (Cheney and Gould 1997, Hough and Albini 1978, Johansen 1987, Wade 1995, Wade and Lunsford 1989, Wade and others 1993).

Hazard-reduction burning— Prescribed fire is often used to reduce fuel loads from dangerous levels to protect forests from wildfire. Most wildfires are accidental; campfires, debris burning, or sparks from machinery are common ignition sources. Burning embers carried aloft by the convection column (rising hot air and gases) may ignite numerous spot fires far away from the main fire. Nevertheless, arson remains a serious problem in southern forests. Fires set by arsonists are difficult to control because they often occur during times of extreme fire danger. Wildfires in recently harvested stands can be intense because of heavy fuel loadings (Sanders and Van Lear 1987).

Pine stands usually develop an understory of hardwoods, shrubs, and vines. When draped with pine needles, this understory becomes highly flammable. If the condition extends over a large area, the whole forest is at risk of destruction by wildfire. In hardwood stands, rhododendron and mountain laurel often form thickets of highly flammable fuels, which allow fire to climb into the canopy. Prescribed fire is an economical way to reduce dangerous fuel accumulations. Wildfires that burn into areas previously subjected to prescribed fires cause less damage and are controlled more easily. The appropriate interval between prescribed burns for fuel reduction varies with several factors, including the rate of fuel accumulation, which is high in pine stands in the Coastal Plain because of the rank understory. Past wildfire occurrence and the values at risk are other factors to consider. The interval between fires in pine stands can be annual, but a 3- to 4-year cycle between fires usually is adequate after an initial fuel reduction burn (Wade and Lunsford 1989).

Fire for regeneration— Judicious use of fire reduces the large amount of highly flammable fine woody material present after clearcutting by more than 90 percent (Sanders and Van Lear 1987). Site-preparation burns in pine plantations are normally conducted in the summer and are of moderate to high intensity. They are used to reduce logging debris, control hardwood sprouts, and improve the plantability of the site. Because of their intensity, these burns must be conducted under the proper fuel- and soil-moisture conditions to prevent damage to the soil, especially in the steep terrain of the Southern Appalachians (Swift and others 1993, Van Lear and Waldrop 1989). Broadcast burning late in the summer following long periods without rain can completely remove organic layers from the soil. Such burns reduce logging debris, ensuring that the site will be plantable, but they can cause site damage from accelerated erosion and loss of nutrients and organic matter. In addition, severe burns may contribute to poor initial survival of planted seedlings because of the loss of mulching effects of a residual forest floor. Both onsite and offsite damage from broadcast burning can be minimized by burning earlier in the summer, soon after soaking rains.

Prescribed fire prior to harvest is used to prepare seedbeds for natural regeneration of pine. Low-intensity burns are used to protect the stand that is being regenerated when seed trees are retained as future cavity trees for red-cockaded woodpeckers. One or more winter burns may be required to reduce fuel loadings. A final summer burn is used to prepare the seedbed and reduce the vigor of understory hardwoods. Dormant season logging further enhances seedbed preparation and allows seeds to germinate the following spring.

Mixed pine-hardwood stands can be regenerated after clearcutting in the Southern Appalachians with minimal adverse site effects using the fell-and-burn technique (Abercrombie and Sims 1986, Danielovich and others 1987, Phillips and Abercrombie 1987). As the name suggests, fell-and-burn requires two steps after clearcutting of hardwood or pine-hardwood stands. First, residual stems over 6 feet tall are felled with chainsaws during early spring after full leaf development when carbohydrate reserves in the roots are low. Allowing full leaf development is important for two reasons: (1) leaves on the felled trees speed the drying of small twigs and branches, which serve as fuel for the broadcast burn; and (2) leafing out reduces root reserves and therefore reduces the vigor of hardwood sprouts. The harvested stand is burned in midsummer, within 24 to 48 hours after a soaking rain. The damp forest floor reduces fuel consumption, minimizing heat penetration into the soil and protecting against erosion. Pine seedlings, planted at a wide spacing the following winter, generally compete well with hardwood coppice.

Using fire to regenerate hardwoods generally has not been recommended because of the fear of damaging stem quality and because of the danger of erosion, particularly on steep slopes (Van Lear and Waldrop 1989). Nevertheless, many oak stands that currently occupy better sites in the Appalachians no doubt became established 60 to 100 years ago when burning was a common practice. Observations of conditions after wildfires are the basis for avoiding burning in hardwoods. Wildfires, however, burn with higher intensity and severity than prescribed fires (Abell 1932, Nelson and others 1933, Wendel and Smith 1986). A low-intensity winter backing fire in mature hardwood stands probably has little adverse effect on crop trees (Sanders and others 1987).

Excluding fire or other disturbances like grazing from mature oak stands may have altered the ecology of mixed-oak, cove hardwood, and pine-hardwood cover types to the detriment of advanced oak regeneration (Little 1974, Van Lear and Johnson 1983). Fires every few years may be the key to enabling oaks to become dominant over their associates in the advance regeneration pool. Oak seedlings are less susceptible to root kill by fire than other species, providing oaks a competitive advantage (Langdon 1981, Niering and others 1970, Swann 1970). The combination of season, frequency, and number of burns to foster oak regeneration in the Appalachians has not been determined, but multiple prescribed burns are probably necessary to promote development of advance oak regeneration prior to harvest (Brose and others 2001, Carvell and Tryon 1961, Keetch 1944, Thor and Nichols 1974). Oak seedlings initially may be more readily established on burned areas in part because the openings encourage activity by blue jays. Jays hoard and scatter acorns, and they seek out areas of thin litter, low vegetation, and full sunlight to bury nuts (Healy 1988). Germination can be enhanced by fire as weevil and beetle species that prey on germinating acorns are reduced on burned seedbeds (Galford and others 1988). Once established, subsequent fires favor oak seedlings over other hardwoods, and single prescribed fires have little effect on species composition in the understory (Augspurger and others 1987, Johnson 1974, Teuke and Van Lear 1982, Waldrop and others 1985, Wendel and Smith 1986).

The task of regenerating oaks, particularly northern red oak, is especially challenging on moist, fertile cove sites. Fire exclusion allows other understory species to compete vigorously with oak seedlings and usually overtop them (McGee 1979). In addition, control of the subcanopy and midstory is necessary to allow enough light to reach the forest floor and favor advance oak regeneration (Van Lear and Waldrop 1988). Fire has been successful for regenerating yellow-poplar on cove sites. This shade-intolerant species is well adapted to fire disturbance. Its light seeds are disseminated by wind and gravity, and they germinate rapidly on fire-prepared seedbeds. Yellow-poplar seeds also remain viable in the forest floor for 8 to 10 years (Little 1967) and will germinate after a fire creates the needed site conditions (McCarthy 1933, Shearin and others 1972, Sims 1932).

Management of competing vegetation—Prescribed burning is used in pine stands to control competing hardwoods that develop from root or stump sprouts after harvesting, or that encroach from adjacent areas such as depressional wetlands. Control is desirable to decrease competition for water, nutrients, and growing space; to reduce risk of wildfire damage in stands with palmetto, gallberry, or wax myrtle understories; and to aid in stand management and regeneration. In most situations, total eradication of the understory and midstory is neither practical nor desirable. Dormant-season burning can reduce the size, but not the number of hardwood stems in understories. Effects depend on the frequency and timing of prescribed fires (Thor and Nichols 1974, Waldrop and others 1987). Low-intensity fires generally kill most hardwood stems up to 3 inches in diameter. Summer fires are more effective than winter fires in killing hardwood rootstocks, but numerous summer fires in successive years are necessary (Waldrop and others 1987).

Periodic prescribed burns can control the size of hardwoods, reduce wildfire hazard, and facilitate stand regeneration. Burning at about 5-year intervals controls the size of sprouts developing from topkilled rootstocks. By controlling the size of understory hardwoods, pines can be maintained more easily on sites where they are the species of choice. If not controlled, hardwoods will form a midstory and capture the site once the pine is harvested (Wade and Lunsford 1989). If a large pine component is desired in the next rotation, these unmerchantable stems must be removed during site preparation at additional expense and risk of compaction.

Prescribed fire shows promise for the control of laurel and rhododendron in the Southern Appalachian Mountains. Fire suppression in this region has resulted in dense stands of these evergreen shrubs. These thickets compete with and substantially limit reproduction and growth of both woody and herbaceous vegetation (Swift and others 1993, Van Lear and Johnson 1983) and therefore are thought to have a major negative impact on hardwood species. Hence, the objective of many prescribed burns in the Southern Appalachians is the control of these evergreen species. Fire initially decreases mountain laurel density, but, in time, laurel regains dominance in the understory because it sprouts quickly after fire or fell-and-burn treatment (Elliott and others 1999). Mountain laurel sprouts grow slowly, however, allowing planted pine and other species to get established in the midstory and overstory before this shrub dominates the understory (Williams and Waldrop 1995).

Protection of threatened and endangered species and unique plant communities—Some threatened and endangered species require fire to become established and survive. Although the role of fire in the ecology of many threatened and endangered species is not well understood, fire has played an essential role in maintaining most ecosystems in the South (Spurr and Barnes 1980). The once extensive longleaf pine ecosystem was fire maintained (Stout and Marion 1993, Ware and others 1993). The forest mosaic of the Southern Appalachians was largely a product of fire disturbances interacting with complex topography. For example, the grassy balds on the summits of high Appalachian peaks may have been created and maintained by fire (Clements 1936), though other explanations are credible (Whittaker 1956).

Many plants have structural adaptations, specialized tissues, or reproductive features that favor them in a fire-dominated environment. Such traits suggest a close association with fire over a very long period of time. Many endemics are only found the first 1 to 2 years after a fire. Changes in the "natural" fire pattern as a result of attempted fire exclusion have led to dramatic decreases in many of these fire-tolerant or fire-dependent species. Many picturesque flowers, including several orchids, currently listed as threatened or endangered, are benefited by fire.

Prescribed burning, however, does not automatically help perpetuate plant and animal species. It may be necessary to burn during the same season in which the site historically burned. The interval between prescribed fires as well as fire intensity may be important. The individual habitat requirements of a species must therefore be understood before fire can be prescribed to benefit that species.

Fires affect vegetation by altering or maintaining successional stages. When fire was more frequent in the South, fire-dependent or fire-associated species dominated the overstory and understory of many forest stands. In the absence of fire and other similar disturbances, forests have gradually changed composition from predominantly longleaf pine and pine-hardwood to communities dominated by other pines in the Coastal Plain and hardwoods in the mountains and Piedmont. When fire is excluded or suppressed, fire-intolerant hardwoods compete with pine species. Many threatened, endangered, or sensitive plants are understory or midstory plants of fire-dominated communities. For example, mountain golden heather, turkey-beard, sand-myrtle, and twisted-head spike-moss grow in the Appalachians on ledge habitats created and kept open by natural fires and severe weather (Morse 1988). Burning also enhances habitat preferences of several endangered animal species, including the Florida panther, gopher tortoise, indigo snake, and red-cockaded woodpecker (Wade and Lunsford 1989).

Manipulation of wildlife habitat—Prescribed fire improves habitats of certain wildlife species, but it also degrades habitats for other species. Each of the hundreds of wildlife species in the South responds differently to fire, depending upon the frequency, intensity, severity, and season of burning. To effectively use prescribed fire to benefit wildlife requires an understanding of the habitat requirements of each species (Harlow and Van Lear 1981, 1987; Lyon and others 1978; Wood 1981). Some general guidelines for burning to enhance habitat for game species are shown in table 25.2.

Prescribed burns to improve wildlife habitat in existing pine stands historically have been conducted in the winter (Mobley and others 1978) to avoid the spring nesting season. Burns at about 3- to 5-year intervals favor deer and turkey. On the lower Coastal Plain, bobwhite quail are favored by burning at 1- to 2-year intervals, and some results indicate that growing season burns can be used where control of invasive hardwoods is needed (Brennan and others 1998). Appropriate burning frequencies for other species are not well known. Low-intensity burns in hardwood or mixed pine-hardwood stands improve wildlife habitat by increasing sprouting of advance regeneration and stimulating production of herbaceous forage. More intense site-preparation burns can also be beneficial where they increase the abundance of legumes and other herbaceous and perennial plants that are preferred by many wildlife species.

Effects of Prescribed Burning

Soil—Many factors, including fire intensity, ambient temperature, vegetation type, and soil moisture influence the effects of fire on the soil (Wells and others 1979). Low-intensity prescribed fires have few, if any, adverse effects on soil properties; in some cases such fires may improve soil properties (McKee 1982). Repeated burning over a long period may affect levels of available phosphorus, exchangeable calcium, and organic matter content of mineral soil. Fire volatilizes nitrogen from the forest floor, but the losses are often offset by increased activity of nitrogen-fixing soil microorganisms after the fire. Calcium and phosphorus may be lost from the forest floor but are partially retained in lower mineral soil horizons. Low-intensity burns have little, if any, adverse effect on soil erosion even on relatively steep slopes (Brender and Cooper 1968, Cushwa and others 1971, Goebel and others 1967).

Prescribed burns conducted when the soil and fuel are too dry can cause severe damage. Broadcast burns conducted under these conditions can remove the entire forest floor and accelerate erosion in steep terrain. High-intensity prescribed fires have a temporary negative effect on site nutrient status resulting from

Table 25.2—Prescribed burning regimes to improve wildlife habitat

Species to benefit	Time of burn	Size of burn	Type of fire	Frequency	Remarks
Deer	Winter preferred	Small or leave unburned areas	Backing fire or point-source fires	2 to 4 years	Want to promote sprouting and keep browse within reach. Repeat summer fires may kill some rootstocks.
Turkey	Winter preferred; summer burns in July-August	Small or leave unburned areas	Backing fire or point-source fires	2 to 4 years	Avoid April through June nesting season.
Quail	Late winter	25 or more acres	Not critical; do not ring fire	1 to 2 years	Avoid April through June nesting season, although summer burns may be used. Leave unburned patches and thickets.
Dove	Winter	Not critical	Not critical; do not ring fire	Not critical	Leave unburned patches and thickets.
Waterfowl	Late fall or winter	Not critical	Heading fire	2 or more years	Marshland only. Do not burn in hardwood swamps.

Source: From table, p. 46 in Wade and Lunsford 1989.

volatilization of nitrogen and sulfur, plus some cation loss due to ash convection. Such effects are short-lived after low-intensity fires, but recovery is not as rapid after severe fires.

Site-preparation burns of high intensity with high fuel loads and low soil moisture may damage soil by overheating. When burning is done with soil moisture near field capacity, however, little heating damage will occur (DeBano and others 1977). Fires that burn completely to mineral soil may accelerate soil erosion in steep terrain. Soil loss after severe burns can exceed 200 tons per acre per year in the Piedmont (Van Lear and Kapeluck 1989). Infiltration is decreased, and run-off and sediment yield increased after severe burns in the Southern Appalachians (Robichaud and Waldrop 1994). Such losses have not been documented in the South, but they appear to be negligible after prescribed burns (Van Lear and Danielovich 1988).

Vegetation—Plants in fire-prone ecosystems have adapted to fire in various ways, including thickening of bark, ability to resprout from below the soil surface, and dispersing seeds. Some trees have thick insulating bark, which protects them from the scorching heat of surface fires (Hare 1965). Mature longleaf pine is well known for its resistance to fire damage because of its thick bark. Slash, loblolly, and shortleaf pines also generally survive bole scorch when they reach sapling size or larger (Komarek 1974). Virginia pine and white pine tend to have thinner bark and are more susceptible to fire damage. However, when pine trees are young, crown scorch rather than damage to the bole is the principal cause of mortality (Cooper and Altobellis 1969, Storey and Merkel 1960). All southern pine species except longleaf are generally both crown-killed and stem-girdled when less than about 1- to 2-inch ground-line diameter, although most species can produce basal sprouts when very young. As the trees increase in size, bud kill rather than stem girdling is likely to be the culprit in periodically burned stands.

Southern pines have the ability to leaf out soon after defoliation from crown scorch (Komarek 1974). Trees are most susceptible to crown scorch during the growing season, when buds are elongating and not protected by needles. Diameter growth apparently is not significantly affected when crown scorch and root damage are minimal (Wade and Johansen 1986).

Aboveground portions of hardwood species are not as resistant to fire damage as conifers, primarily because of thinner bark. Bark thickness is not as critical to hardwood survival in Appalachian hardwoods, because most fires burn in light fuels and are of low intensity (Komarek 1974). There are some exceptions, however, such as when understories of mountain laurel produce high-intensity fires in hardwood stands. Some hardwoods develop exceptionally thick bark upon maturity. According to Nelson and others (1933), yellow-poplar is one of the most fire-resistant species in the East when its bark thickness exceeds 0.5 inch. On the Coastal Plain, many hardwood stems over 6 inches in diameter at breast height survived after 30 years of low-intensity annual and biennial burning (Waldrop and others 1992) with little or no damage to boles.

Hardwoods sprout, generally from the base of the stem or from root suckers, when tops are killed. Suppressed buds at or below ground level often survive the heat of a surface fire and sprout in response to the loss of apical dominance (Augspurger and others 1987, Waldrop and others 1985). Although many sprouts may develop from a stump, over time they thin down to one or a few per stump.

Many species have adapted to a high-frequency fire regime by developing light seeds, which can be disseminated over large areas by wind and gravity. These light-seeded species often pioneer on burned seedbeds. Some species, such as yellow-poplar, produce seeds that remain viable for years in the duff. Yellow-poplar seeds stored in the lower duff germinate rapidly after low-intensity prescribed fires (Shearin and others 1972).

Water quality—Effects of prescribed fire on water quality vary, depending on fire intensity, type and amount of vegetation present, ambient temperature, terrain, and other factors. The major problems associated with prescribed fire and water quality are potential increases in sedimentation and, to a lesser degree, increases in dissolved salts in streamflow (Tiedemann and others 1979). However, most studies in the South indicate that effects of prescribed fire on water quality are minor and of short duration when compared with effects of other forest practices (Brender and Cooper 1968). For example, when prescribed fires are conducted properly, nutrient loss and stream sedimentation are likely to be minor compared with those resulting from mechanical methods of site preparation (Douglass and Goodwin 1980, Douglass and Van Lear 1982, Ursic 1970). Even intense broadcast burns may disturb the root mat very little, leaving its soil-holding properties intact. Furthermore, slash tends to be randomly distributed over logged areas and is seldom completely removed by broadcast burning. Therefore, the root mat, residual forest floor materials, and incompletely consumed slash form debris dams that trap much of the sediment moving downslope (Dissmeyer and Foster 1980). Also rapid regrowth in the South quickly protects sites.

Only a few studies in the South have documented the effects of prescribed fire on nutrient concentrations in streams or ground water. Low-intensity prescribed fire had no major impact on stormflow or soil-solution nutrient levels (Douglass and Van Lear 1982, Richter and others 1982). Severe wildfire in heavy fuels in mountainous terrain had no adverse effects on water quality (Neary and Currier 1982). Research from Western States documented several cases where slash burning increased nitrate-N levels in streamflow. In no case, however, did burning cause nitrate-N levels to exceed the recommended U.S. Environmental Protection Agency standard of 10 parts per million for drinking water. Phosphorus and major cations often increased in streamflow and the soil solution, but the effects were of short duration and of a magnitude not considered damaging to surface water or site productivity (Tiedemann and others 1979).

Smoke Management

All woods fires produce smoke. Smoke from prescribed burning is a problem when it creates an annoyance or nuisance, and when it negatively affects human health and safety. Prescribed burners, therefore, must be able to predict smoke production and movement before they ignite a fire.

Problem Smoke

Smoke can contribute to regional haze and may be considered an annoyance by recreationists and residents in scenic areas. Smoke is a nuisance when it irritates the eyes and mucous membranes of the nose and throat, or when it deposits soot on homes. Smoke exacerbates health problems for those with respiratory difficulty or other illnesses. Smoke is a safety hazard when it impedes visibility of drivers of motor vehicles. Problem smoke is chronic in the South because of three factors:

1. A lot of smoke is produced by wildfires and prescribed fires.
2. A lot of people live in interfaces between forests and urban areas.
3. Southern meteorology produces air masses that entrap smoke close to the ground at night.

Of the South's 200 million acres of forest, 4 to 6 million acres burn annually. The area burned is the most in any region of the country. Prescribed burning is used to manage fuel loads and reduce the risk of catastrophic wildfire. The long growing season and warm, humid climate create conditions for rapid buildup of live and dead fuels, which contribute to greater smoke production when burned.

The southern forests are crisscrossed by a dense road network, even in predominantly rural areas. Population density is increasing in many areas of the South with an expanding interface between forests and dwellings. The population living within or near southern forests is greater than in other parts of the country where prescribed fire is widely used. In addition, many people travel through the South who are unaware of smoke and fog hazards.

Climate and weather contribute to problem smoke in several ways. First, prescribed burning is conducted when soil and litter are moist in order to avoid damaging tree roots. Fires in moist fuels burn less efficiently and smolder longer than fires in dry fuels, increasing smoke production. In addition, inefficient combustion produces less heat to carry smoke aloft, so smoke stays close to the ground. Second, shallow valley inversions can develop in the winter, trapping smoke near the ground. Weak drainage winds can carry smoke more than 10 miles, far enough to reach roadways in most areas.

Constituents of Smoke

Particulate matter is the major pollutant in the smoke from prescribed burning (Dieterich 1971, Hall 1972, Sandberg and others 1979). It is a complex mixture of soot, tars, and volatile organic substances, either solid or liquid. Sizes average about 0.1 micron in diameter (McMahon 1977). With low windspeed and high humidity, moisture condenses around particulates and forms dense smoke or combinations of smoke and fog. Reductions in visibility during and after prescribed fires, therefore, have caused numerous highway accidents.

Particulates are not the only emissions from fire. Besides carbon dioxide and water vapor, gaseous hydrocarbons, carbon monoxide, and nitrous oxides are also released (Chi and others 1979). However, only a small proportion (less than 3 percent) of the total national emissions of particulates, carbon monoxide, and hydrocarbons can be attributed to prescribed burning.

Carbon monoxide is a poisonous gas, which may reach toxic levels above and adjacent to prescribed fires, but these concentrations decline rapidly with increasing distance from the flame (McMahon and Ryan 1976). By burning under atmospheric conditions that encourage rapid mixing, the problem of high carbon monoxide levels can be eliminated.

Hydrocarbons are a diverse group of compounds that contain hydrogen, carbon, and their oxygenated derivatives (Hall 1972). Unsaturated hydrocarbons result from the incomplete combustion of organic fuels. Because of their high affinity for oxygen, these compounds may form photochemical smog in the presence of sunlight and oxygen-donating compounds. Methane, ethylene, and hundreds of other gases are released in prescribed burning. Most of the hydrocarbons released during prescribed fires are quite different from those released in internal combustion engines.

Nitrogen oxides are not likely to be released in significant quantities during prescribed burning. The threshold temperature for the release of nitrogen oxides is 1,500 °C, which is hotter than the temperatures normally occurring in prescribed fires (McMahon and Ryan 1976). Nitrogen is volatilized, with the amount released varying with the temperature. At temperatures of 500 °C, 100 percent of the nitrogen is volatilized; at temperatures of 200 to 300 °C, only about 50 percent of the nitrogen is lost (Dunn and DeBano 1977). Sulfur dioxide emissions from prescribed fires are of minor importance since the sulfur concentration of most forest fuels is less than 0.2 percent.

Smoke Management

An extensive wildland-urban interface, a dense road network, and up to 6 million acres of prescribed burning make smoke the foremost forestry-related air quality problem. The risk of smoke movement into sensitive areas such as airports, highways, and communities is probably the major threat to the continued use of prescribed burning. Public concern is likely to occur before levels of smoke exposure violate National Ambient Air Quality Standards. Because of the potentially serious effects of prescribed fire on air quality and its value in forest management, guidelines for smoke management have been developed by the Forest Service to reduce the atmospheric impacts of prescribed fire (U.S. Department of Agriculture, Forest Service 1976). The guidelines recommend five steps: (1) plot the trajectory of the smoke; (2) identify smoke-sensitive areas such as highways, airports, hospitals, etc.; (3) identify critical targets close to the burn or those that already have an air pollution problem; (4) determine the fuel type to be burned; and (5) minimize risk by burning under atmospheric conditions that hasten smoke dispersion, or by using appropriate ignition patterns to reduce smoke pollution.

Burning under proper weather conditions can reduce the impact of smoke. The fire manager should have current weather forecasts with enough information to predict smoke behavior. Both surface weather and upper atmospheric conditions are important. Burning should be conducted when wind is moving away from sensitive areas such as highways and homes. The atmosphere should be slightly unstable for optimum smoke dispersal without loss of fire control.

The ability to predict smoke movement is critical to meeting these guidelines and protecting the public. Efforts to avoid smoke moving to sensitive areas are often complicated by highly variable weather during the burning season in the South.

Weather fronts pass frequently in the South in the winter, producing variable but predictable wind directions. Coastal forests are subject to wind shifts brought on by sea breezes during the day and land breezes at night. These circulations are inconsistent from one day to the next. Regional weather systems also interact with the Appalachian Mountains, producing sudden wind shifts, large changes in wind direction, and a lowering of mixing heights.

Several approaches are being taken to improve the ability to predict smoke movement. Computer models are in operation or being developed to predict smoke movement over the southern landscape. Daytime movement and concentration of particulate matter in smoke, assuming level terrain and unchanging winds, is modeled by VSMOKE (Lavdas 1996). Managers use VSMOKE to assess where smoke from prescribed burns might impact sensitive targets. Movement of smoke trapped near the ground at night can be simulated in the complex terrain of the Piedmont by the PB-Piedmont model (Achtemeier 2001). PB-Piedmont does not predict smoke concentrations, because we do not have good information on emissions from smoldering combustion. Two sister models are planned, one for the Appalachian Mountains and one for coastal areas influenced by sea/land circulations.

High-resolution weather prediction models promise to increase accuracy in prediction of windspeed and direction, as well as mixing height, at time and spatial scales needed by land managers. Accurate predictions of sea/land breezes and associated changes in temperature, wind direction, atmospheric stability, and mixing height are critical. The Florida Division of Forestry is a leader in the use of high-resolution modeling for forestry in the South. Recently the USDA Forest Service, The University of Georgia, and other partners have initiated a Southern High Resolution Modeling Consortium to develop new models and deliver them to clients.

Restoring Fire into Southern Ecosystems

The adverse effects of 70 years of fire suppression are evident in many ecosystems in the South, and the risk of catastrophic wildfires has increased. Many of these ecosystems can be restored with the judicious reintroduction of fire, sometimes in combination with chemical or mechanical methods. Reintroduction of fire is driven by two objectives: (1) fuel management to reduce the risk of wildfire; and (2) restoration of unique, fire-prone ecosystems that support many threatened, endangered, and sensitive plant and animal species.

The long association of southern vegetation with fire has resulted in key species developing traits that favor them in fire-prone ecosystems (Christensen 1977, Landers 1991). If a certain threshold has not been reached, the natural resiliency of these systems allows them to recover if fire is reintroduced (Vogl 1976). Once this threshold has been exceeded, however, natural processes can no longer rectify the situation in a reasonable amount of time. Thus, many components of the original ecosystem cannot survive long-term without fire (Garren 1943). Restoration of longleaf pine grasslands is the goal of many organizations, but longleaf is not the only candidate for restoration of the historic role of fire. Table Mountain pine, the shortleaf pine-bluestem ecosystem, and oak types can benefit from restoration of periodic burning.

Southern pines, in general, develop increasing fire resistance as they age, but longleaf pine is the only tree species able to cope with annual or biennial fires throughout its lifespan. This is the primary reason it once dominated about 75 million acres (Betts 1954, Frost 1993) stretching from southern Virginia through central Florida to east Texas. Chapman (1932) believed this forest type occupied the largest area in the United States dominated by one tree species. Longleaf pine also occurred in association with other species on an additional 18 million acres (Frost 1993).

The longleaf-grassland ecosystem is one of the most species-rich ecosystems found outside the tropics (Peet and Allard 1993). The flora and fauna that dominate this ecosystem have well-developed adaptations to chronic fire. This fire regime maintained a two-tiered structure of an open longleaf overstory and a diverse groundcover dominated by bunchgrasses. Density and phenology of numerous groundcover plants are influenced by the season of burn (Platt and others 1988, Streng and others 1993); simply reintroducing periodic burning, therefore, may not accomplish the desired restoration. About 191 taxa of vascular plants associated with the longleaf-bunchgrass system are classified as threatened or endangered (Walker 1993). The fauna also includes many endemics that are listed as threatened or endangered. Overviews of the plant and animal communities that form this ecosystem can be found in Bridges and Orzell (1989), Harcombe and others (1993), Myers and Ewel (1990), Platt and Rathbun (1993), Skeen and others (1993), Stout and Marion (1993), and Ware and others (1993).

Typical vegetation in the Ouachita Mountains at the beginning of the last century included open woodlands of pine and hardwood, with big bluestem and other grasses in the understory (Foti and others 1999). Fire exclusion and infrequent thinning of second-growth shortleaf pine and pine-hardwood stands resulted in denser stands than historical fire regimes would have produced. Restoration of the shortleaf pine-bluestem habitat is being attempted on 155,000 acres of the Ouachita National Forest in western Arkansas and eastern Oklahoma. Restoration treatments include reducing overstory basal area by harvesting and mechanical reduction of midstory trees, accompanied by reintroduction of fire. The midstory reduction treatments will reduce fuel loads and should lead to fewer wildfires.

The prescriptions include removal of most midstory hardwoods, thinning from below in overstory and midstory pines, and reintroducing surface fires on a 1- to 3-year return interval. These treatments have been effective in restoring many underrepresented species in the landscape, such as purple coneflower, bobwhite quail, red-cockaded woodpecker, Bachman's sparrow, and eastern wild turkey (Bukenhofer and Hedrick 1997). In addition, there is roughly seven times the preferred deer forage in treated versus untreated areas (Masters and others 1996).

The long-term effects of fire exclusion in the Appalachians are becoming increasingly apparent (Williams 1998). Most pine stands are now degraded and succeeding toward hardwood dominance (Williams 1998, Williams and Johnson 1992). The increased incidence of bark beetle attacks in these stressed, aging stands is accelerating this successional trend. On xeric mixed pine-hardwood ridges in the Southern Appalachians, fire has been advocated to restore diversity and productivity (Swift and others 1993; Vose and others 1994, 1997). A winter fire that reduces surface fuels, followed by a summer fire, can control competing hardwoods best (Elliott and others 1999).

Interest has been expressed in restoring Table Mountain pine (Waldrop and Brose 1999), a rare community type in the Southern Appalachians (Southern Appalachian Man and the Biosphere 1996). Questions regarding the necessity of crown fires to restore Table Mountain pine are still unresolved (Waldrop and Brose 1999, Whittaker 1956), but are the subject of ongoing studies. Extreme fire intensity may not be needed to regenerate Table Mountain pine (Waldrop and Brose 1999). Fires of low and medium-low intensity produced abundant pine regeneration, but may not have killed enough of the overstory to prevent shading. High-intensity fires, on the other hand, killed almost all overstory trees but may have destroyed some seeds. Fires of medium-high intensity may be the best choice; such fires killed overstory trees and allowed abundant regeneration.

A series of periodic fires prior to harvest of mature hardwood stands may increase the number of oaks in the advance regeneration pool (Brose and Van Lear 1998; Brose and others 1999a, 1999b; Little 1974), an important consideration in the reestablishment of stands with a large oak component. Periodic fires at intervals of several years favor species that are more fire-resistant than their competitors, and oak seedlings resist root-kill by fire better than their competitors (Niering and others 1970, Swann 1970, Teuke and Van Lear 1982, Thor and Nichols 1974). Many have noticed that intense fires in mixed hardwood stands may favor oak (Carvell and Maxey 1969, Keetch 1944), but this is not always the case, and competitors such as red maple may increase in abundance (McGee 1979). Much remains to be learned about the use of fire to alter species composition in hardwood stands.

Literature Cited

Abell, M.S. 1932. Much heartrot enters white oaks through fire wounds. Forest Worker. 8(6): 10.

Abercrombie, James A., Jr.; Sims, Daniel H. 1986. Fell and burn for low-cost site preparation. Forest Farmer. 46(1): 14–17.

Achtemeier, G.L. 2001. Simulating nocturnal smoke movement. Fire Management Today. 61: 28–33.

Albrecht, Michael H.; Mattson, Katharine E. 1977. Fuel weights by types for Piedmont and mountain regions of North Carolina. For. Note 30. Raleigh, NC: North Carolina Forest Service, Office of Forest Resources. 19 p.

Andrews, E.F. 1917. Agency of fire in propagation of longleaf pine. Botanical Gazette. 64: 497–508.

Augspurger, M.K.; Van Lear, D.H.; Cox, S.K.; Phillips, D.R. 1987. Regeneration of hardwood coppice following clearcutting with and without prescribed fire. In: Phillips, Douglas R., comp. Proceedings of the fourth biennial southern silvicultural research conference. Gen. Tech. Rep. SE–42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 89–92.

Baker, James B.; Langdon, O. Gordon. 1990. *Pinus taeda* L. loblolly pine. In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America: conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 497–512. Vol. 1.

Barden, L.S. 1997. Historic prairies in the Piedmont of North and South Carolina, U.S.A. Natural Areas Journal. 17(2): 149–152.

Barden, L.S.; Woods, F.W. 1974. Characteristics of lightning fires in southern Appalachian forests. In: Proceedings, 13th annual Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 345–361.

Barden, Lawrence S. 1977. Self-maintaining populations of *Pinus pungens* Lam. in the Southern Appalachian Mountains. Castanea. 42: 316–323.

Barrett, J.A. 1994. Regional silviculture of the United States. 3rd ed. New York: John Wiley. 643 p.

Barrett, L.I.; Downs, A.A. 1943. Hardwood invasion in pine forests of the Piedmont plateau. Journal of Agricultural Research. 67: 111–128.

Betts, H.S. 1954. The southern pines. American woods series. Washington, DC: U.S. Department of Agriculture, Forest Service. 13 p.

Blaisdell, R.S.; Wooten, J.; Godfrey, R.K. 1974. The role of magnolia and beech in forest processes in the Tallahassee, Florida, Thomasville, Georgia area. In: Proceedings, 13th annual Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 363–397.

Blow, Frank E. 1955. Quality and hydrologic characteristics of litter under upland oak forests in eastern Tennessee. Journal of Forestry. 53: 190–195.

Boyer, W.D. 1990. *Pinus palustris* Mill. longleaf pine. In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America: conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 405–412. Vol. 1.

Braun, E.L. 1950. The deciduous forests of Eastern North America. New York: Hafner Press. 596 p.

Brender, E.V. 1974. Impact of past land use of the lower Piedmont forest. Journal of Forestry. 72(1): 34–36.

Brender, Ernest V.; Cooper, Robert W. 1968. Prescribed burning in Georgia's Piedmont loblolly pine stands. Journal of Forestry. 66: 31–36.

Brender, Ernest V.; Merrick, Elliott. 1950. Early settlement and land use in the present Toccoa Experimental Forest. Scientific Monthly. 71: 318–325.

Brennan, L.A.; Engstrom, R.T.; Palmer, W.E. [and others]. 1998. Whither wildlife without fire? In: Wadsworth, K.G., ed. Transactions, 63rd North American wildlife and natural resources conference. Washington, DC: Wildlife Management Institute: 402–414.

Bridges, Edwin L.; Orzell, Steve L. 1989. Longleaf pine communities of the west Gulf Coastal Plain. Natural Areas Journal. 9(4): 246–263.

Brose, P.H.; Van Lear, D.H.; Cooper, R. 1999b. Using shelterwood harvests and prescribed fire to regenerate oak stands on productive upland sites. Forest Ecology and Management. 113: 125–141.

Brose, Patrick; Schuler, Thomas; Van Lear, David; Berst, John. 2001. Bringing fire back: the changing regimes of the Appalachian mixed-oak forests. Journal of Forestry. 99(11): 30–35.

Brose, Patrick H.; Tainter, Frank; Waldrop, Thomas A. 2002. Regeneration history of three Table Mountain/pitch pine stands in northern Georgia. In: Outcalt, Kenneth W., ed. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 296-301.

Brose, Patrick; Van Lear, David. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Canadian Journal of Forest Research. 28: 331–339.

Brose, Patrick; Van Lear, David H.; Keyser, Patrick D. 1999a. A shelterwood-burn technique for regenerating productive upland oak sites in the Piedmont region. Southern Journal of Applied Forestry. 23(3): 158–163.

Brown, A.A.; Davis, K.P. 1973. Forest fire: control and use. New York: McGraw-Hill Book Co. [Number of pages unknown].

Brown, J.K. 2000. Introduction and fire regimes. In: Brown, J.K.; Smith, J.K., eds. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS–42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 1–8. Vol. 2.

Brown, J.K.; Smith, J.K., eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS–42. Ogden, UT: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station. 257 p. Vol. 2.

Buckner, E. 1983. Archaeological and historical basis for forest succession in Eastern North America. In: Proceedings, 1982 Society of American Foresters national convention. Publ. 83–04. Bethesda, MD: Society of American Foresters: 182–187.

Buell, M.F.; Buell, H.F.; Small, J.A. 1954. Fire in the history of Mettler's Woods. Bulletin of the Torrey Botanical Club. 81: 253–255.

Bukenhofer, G.A.; Hedrick, L.D. 1997. Shortleaf pine/bluestem grass ecosystem renewal in the Ouachita Mountains. In: Transactions of the 62nd North American wildlife and natural resources conference. Washington, DC: Wildlife Management Institute: 509–515.

Carvell, K.L.; Tryon, E.H. 1961. The effect of environmental factors on the abundance of oak regeneration beneath mature oak stands. Forest Science. 7: 98–105.

Carvell, Kenneth L.; Maxey, William R. 1969. Wildfire adversely affects composition of cove hardwood stands. [Place of publication unknown]: West Virginia Agricultural Experiment Station Bull. 2(2): 4–5.

Chaiken, L.E. 1949. The behavior and control of understory hardwoods in loblolly pine stands. Tech. Note 72. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 27 p.

Chapman, H.H. 1932. Is the longleaf type a climax? Ecology. 13: 328–334.

Cheney, N.P.; Gould, J.S. 1997. Fire growth and acceleration. International Journal of Wildland Fire. 7(1): 1–5. [Letter to the editor].

Chi, C.T.; Horn, D.A.; Reznik, R.B. 1979. Source assessment: prescribed burning, state of the art. EPA–600/2–79–019h. Research Triangle Park, NC: U.S. Environmental Protection Agency, Industrial Environment Research Laboratory. 107 p.

Christensen, N.L. 1981. Fire regimes in southeastern ecosystems. In: Fire regimes and ecosystem properties. Gen. Tech. Rep. WO–26. Washington, DC: U.S. Department of Agriculture, Forest Service: 112–136.

Christensen, N.L.; Wilbur, R.B.; McClean, J.S. 1988. Soil-vegetation correlations in the pocosins of Croatan National Forest, North Carolina. Biol. Rep. 88 (28). Washington, DC: U.S. Fish and Wildlife Service. 97 p.

Christensen, Norman L. 1977. Fire in southern forest ecosystems. In: Proceedings: fire by prescription symposium. Atlanta: U.S. Department of Agriculture, Forest Service: 17–24.

Christensen, Norman L. 1993. The effects of fire on nutrient cycles in longleaf pine ecosystems. In: Proceedings, 18th Tall Timbers fire ecology conference: the longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 205–214.

Clements, Frederic E. 1936. Nature and structure of the climax. Journal of Ecology. 24: 252–284.

Cooper, Robert W.; Altobellis, Anthony T. 1969. Fire kill in young loblolly pine. Fire Control Notes. 30: 14–15.

Crosby, John S.; Loomis, Robert M. 1974. Some forest floor fuelbed characteristics of black oak stands in southeast Missouri. Res. Note NC–162. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 4 p.

Cry, G.W. 1965. Tropical cyclones of the North Atlantic Ocean. Tech. Pap. 55. Washington, DC: U.S. Department of Commerce. 148 p.

Cushwa, Charles T.; Hopkins, Melvin; McGinnes, Burd S. 1971. Soil movement in established gullies after a single prescribed burn in the South Carolina Piedmont. Res. Note SE–153. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 4 p.

Cutter, Bruce E.; Guyette, Richard P. 1994. Fire frequency on an oak-hickory ridgetop in the Missouri Ozarks. American Midland Naturalist. 132(2): 393–398.

Danielovich, S.J.; Van Lear, D.H.; Cox, S.K.; Augspurger, M.K. 1987. Burning in Southern Appalachian logging slash—effects of residual vegetation and regrowth. In: Hay, Ronald, L.; Woods, Frank W.; DeSelm, Hal, eds. Proceedings, sixth central hardwood conference. Knoxville, TN: University of Tennessee, Department of Forestry, Wildlife, and Fisheries: 91–97.

Daubenmire, Rexford. 1990. The *magnolia grandifolia* [*grandiflora*]-*Quercus virginiana* forest in Florida. American Midland Naturalist. 123(3): 331–347.

DeBano, L.F.; Dunn, P.H.; Conrad, C.E. 1977. Fire's effect on physical and chemical properties of chaparral soils. In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems. Gen. Tech. Rep. WO–3. Washington, DC: U.S. Department of Agriculture, Forest Service: 65–74.

Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. 1977. The national fire-danger rating system—1978. Gen. Tech. Rep. INT–39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 63 p.

Delcourt, H.R.; Delcourt, P.A 1981. Vegetation maps for North America. Geobotany. 11: 123–165.

Delcourt, H.R.; Delcourt, P.A 1983. Late Quaternary vegetational dynamics and community stability reconsidered. Quaternary Research. 19: 265–271.

Delcourt, H.R.; Delcourt, P.A. 1997. Pre-Columbian Native American use of fire on Southern Appalachian landscapes. Conservation Biology. 11(4): 1010–1014.

Delcourt, P.A.; Delcourt, H.R. 1998. The influence of prehistoric human-set fires on oak-chestnut forests in the Southern Appalachians. Castanea. 63(3): 337–345.

Demmon, E.L. 1929. Fires and forest growth. American Forests. 35(5): 273–276.

Denevan, W.M. 1992. The pristine myth: the landscape of the Americas in 1492. Annals of the Association of American Geographers. 82(3): 369–385.

Dieterich, John H. 1971. Air-quality aspects of prescribed burning. In: Proceedings of a symposium on prescribed burning. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 139–150.

Dissmeyer, George E.; Foster, George R. 1980. A guide for predicting sheet and rill erosion on forest land. Tech. Publ. SA-TP 11. Atlanta: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Southeastern Area. 40 p.

Dobyns, H.F. 1966. Estimating aboriginal American population: an appraisal of techniques with a new hemisphere estimate. Current Anthropology. 7: 395–416.

Dobyns, H.F. 1983. Their numbers become thinned: Native American population dynamics in Eastern North America. Knoxville, TN: University of Tennessee Press. 378 p.

Dorn, William Jennings Bryan; Derks, Scott. 1988. Dorn: of the people—a political way of life. Orangeburg, SC: Sandlapper Publishing. 286 p .

Douglass, J.E.; Van Lear, D.H. 1982. Prescribed burning and water quality of ephemeral streams in the Piedmont of South Carolina. Forest Science. 29: 181–189.

Douglass, James E.; Goodwin, O.C. 1980. Runoff and soil erosion from forest site preparation practices. In: U.S. forestry and water quality: what course in the 80's? Proceedings. Washington, DC: Water Pollution Control Federation: 50–74.

Driver. H.E. 1961. The Indians of North America. Chicago: University of Chicago Press. 632 p.

Dunn, Paul H.; DeBano, Leonard F. 1977. Fire's effect on biological and chemical properties of chaparral soils. In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems. Gen. Tech. Rep. WO–3. Washington, DC: U.S. Department of Agriculture, Forest Service: 75–84.

Edgar, Walter. 1998. South Carolina, a history. Columbia, SC: University of South Carolina Press: 266–268.

Eldredge, I.F. 1911. Fire problems on the Florida National Forest. In: Proceedings, Society of American Foresters. [Place of publication unknown]: [Publisher unknown]. 6: 166–170.

Elliott, Katherine J.; Hendrick, Ronald L.; Major, Amy E. [and others]. 1999. Vegetation dynamics after a prescribed fire in the Southern Appalachians. Forest Ecology and Management. 114: 199–213.

Fagan, B.M. 2000. Ancient North America. 3rd ed. London: Thames and Hudson. 544 p.

Foti, T.; Richards, L.L.; Andre, J.; Voeller, J.E. 1999. Prehistoric and historic changes. In: Ozark-Ouachita Highlands assessment: terrestrial vegetation and wildlife. Rep. 5 of 5. Gen. Tech. Rep. SRS–35. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 7–20. Chapter 2.

Frost, Cecil. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. In: Proceedings, 18th Tall Timbers fire ecology conference. The longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 17–43.

Frost, Cecil. 1998. Presettlement fire frequency regimes of the United States: a first approximation. In: Proceedings, 20th Tall Timbers fire ecology conference: Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tallahassee, FL: Tall Timbers Research Station: 70–81.

Galford, Jimmy R.; Peacock, John W.; Wright, Susan L. 1988. Insects and other pests affecting oak regeneration. In: Smith, H. Clay; Perkey, Arlyn W.; Kidd, William E., Jr., eds. Proceedings of a workshop. Guidelines for regenerating Appalachian hardwood stands. Morgantown, WV: West Virginia University Books: 219–225.

Garren, K.H. 1943. Effects of fire on vegetation of the Southeastern United States. Botanical Review. 9: 617–654.

FIRE

Gilliam, Frank S.; Platt, William J. 1999. Effects of long-term fire exclusion on tree species composition and stand structure in an old-growth *Pinus palustris* (longleaf pine) forest. Plant Ecology. 140: 15–26.

Glitzenstein, Jeff S.; Platt, William J.; Streng, Donna R. 1995. Effects of fire regime and habitat on tree dynamics in north Florida longleaf pine savannas. Ecological Monographs. 65(4): 441–476.

Goebel, N.B.; Brender, E.V.; Cooper, R.W. 1967. Prescribed burning of pine-hardwood stands in the upper Piedmont of South Carolina. For. Res. Ser. 16. Clemson, SC: Clemson University, Department of Forestry. 23 p.

Graves, Henry S. 1910. Protection of forests from fire. Forest Service Bull. 82. [Washington, DC]: U.S. Department of Agriculture, Forest Service. 48 p.

Guyette, R.P.; Dey, D.C. 1997. Fire and logging history at Huckleberry Hollow, Shannon County, Missouri. Rep. 97–1. Missouri Department of Conservation. 8 p.

Hall, J. Alfred. 1972. Forest fuels, prescribed fire, and air quality. Res. Pap. SO–56. New Orleans: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

Hamel, Paul B.; Buckner, Edward R. 1998. How far could a squirrel travel in the treetops? A prehistory of the southern forest. In: Transactions, 63rd North American wildlife and natural resource conference. Washington, DC: Wildlife Management Institute: 309–315.

Harcombe, P.C.; Glitzenstein, J.S.; Knox, R.G. [and others]. 1993. Vegetation of the longleaf pine region of the west Texas gulf plain. In: Proceedings, 18th Tall Timbers fire ecology conference: The longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 83–104.

Hare, Robert C. 1965. Contribution of bark to fire resistance of southern trees. Journal of Forestry. 63: 248–251.

Harlow, R.F.; Van Lear, D.H. 1981. Silvicultural effects on wildlife habitat in the South (an annotated bibliography) 1953–1979. Tech. Pap. 14. Clemson, SC: Clemson University, Department of Forestry. 30 p.

Harlow, R.F.; Van Lear, D.H. 1987. Silvicultural effects on wildlife habitat in the South (an annotated bibliography) 1953–1985. Tech. Pap. 17. Clemson, SC: Clemson University, Department of Forestry. 142 p.

Harmon, Mark E. 1984. Survival of trees after low-intensity surface fires in Great Smoky Mountains National Park. Ecology. 65(3): 796–802.

Healy, William M. 1988. Effects of seed-eating birds and mammals on Appalachian hardwood regeneration. In: Smith, H. Clay; Perkey, Arlyn W.; Kidd, William E., Jr., eds. Proceedings of a workshop: guidelines for regenerating Appalachian hardwood stands. Morgantown, WV: West Virginia University Books: 104–111.

Heyward, F. 1939. The relation of fire to stand composition of longleaf forests. Ecology. 20: 287–304.

Holmes, J.S. 1911. Forest conditions in western North Carolina. Bull. 23. Raleigh, NC: North Carolina Geologic and Economic Survey. 54 p.

Hough, W.A.; Albini, F.A. 1978. Predicting fire behavior in palmetto-gallberry fuel complexes. Res. Pap. SE–174. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 44 p.

Hudson, Charles M. 1982. The southeastern Indians. Knoxville, TN: University of Tennessee Press. 573 p.

Jacobs, W.R. 1974. The tip of the iceberg: pre-Columbian Indian demography and some implications for revisionism. William and Mary Quarterly. 31: 123–133.

Johansen, Ragnar W. 1987. Ignition patterns and prescribed fire behavior in southern pine stands. Georgia For. Res. Pap. 72. Macon, GA: Georgia Forestry Commission, Research Division. 6 p.

Johnson, Paul S. 1974. Survival and growth of northern red oak seedlings following a prescribed burn. Res. Note NC–177. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 3 p.

Keetch, John J. 1944. Sprout development on once-burned and repeatedly burned areas in the Southern Appalachians. Tech. Note 59. [Asheville, NC]: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 3 p.

Kimmerer, Robin W.; Lake, Frank K. 2001. The role of indigenous burning in land management. Journal of Forestry. 99(11): 36–41.

Kirkman, L. Katherine; Drew, Mark B.; West, L.T.; Blood, E.R. 1998. Ecotone characterization between upland longleaf pine/wiregrass stands and seasonally-ponded isolated wetlands. Wetlands. 18(3): 346–364.

Komarek, E.V. 1964. The natural history of lightning. In: Proceedings, third annual Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 139–183.

Komarek, Edwin V. 1974. Effects of fire on temperate forests and related ecosystems: Southeastern United States. In: Kozlowski, Theodore T.; Ahlgren, Charles E., eds. Fire and ecosystems. New York: Academic Press: 251–277.

Kucera, C.L. 1952. An ecological study of a hardwood forest area in central Iowa. Ecological Monographs. 22: 282–299.

Kuchler, A.W. 1964. Potential vegetation of the conterminous United States. Spec. Publ. 36. Washington, DC: American Geographical Society. 116 p.

Landers, J. Larry. 1991. Disturbance influences on pine traits in the Southeastern United States. In: Proceedings, 17th Tall Timbers fire ecology conference: high intensity fire in wildlands: management challenges and options. Tallahassee, FL: Tall Timbers Research Station: 61–98.

Landers, J. Larry; Byrd, Nathan A.; Komarek, Roy. 1990. A holistic approach to managing longleaf pine communities. In: Proceedings of the symposium on the management of longleaf pine. SO–75. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 135–167.

Landers, J. Larry; Van Lear, David H.; Boyer, William D. 1995. The longleaf pine forests of the Southeast: requiem or renaissance? Journal of Forestry. 93(11): 39–44.

Landers, Larry; Wade, Dale. 1994. Disturbance, persistence, and diversity of the longleaf pine-bunchgrass ecosystem. In: Proceedings of the Society of American Foresters 1993 national convention. SAF Publ. 94–01. Bethesda, MD: Society of American Foresters: 182–188.

Langdon, O. Gordon. 1981. Some effects of prescribed fire on understory vegetation in loblolly pine stands. In: Wood, Gene W., ed. Prescribed fire and wildlife in southern forests: proceedings of a symposium. Georgetown, SC: Clemson University, Belle W. Baruch Forest Science Institute: 143–153.

Lavdas, L.G. 1996. Program VSMOKE-users manual. Gen. Tech. Rep. SRS–6. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 147 p.

Lentz, G.H. 1931. Forest fires in the Mississippi bottomlands. Journal of Forestry. 29: 831–832.

Lippincott, Carol L. 1997. Restoration and management implications of *Imperata cylindrica* (cogongrass) invasion in sandhill ecosystems. In: Proceedings, longleaf pine ecosystem restoration symposium at the ninth annual international conference of the society for ecological restoration. Longleaf Alliance Rep. 3. Auburn, AL: Longleaf Alliance: 61–62.

Little, S. 1946. The effects of forest fires on the stand history of New Jersey's pine region. For. Manage. Pap. 2. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 43 p.

Little, S. 1967. Treatments needed to regenerate yellow-poplar in New Jersey and Maryland. Res. Note NE–58. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.

Little, S. 1974. Effects of fire on temperate forests: Northeastern United States. In: Kozlowski, Theodore T.; Ahlgren, Charles E., eds. Fire and ecosystems. New York: Academic Press: 225–250.

Little, S.; Somes, H.A. 1964. Releasing pitch pine sprouts from old stools ineffective. Journal of Forestry. 62: 23–26.

Little, Silas. 1973. Eighteen-year changes in the composition of a stand of *Pinus echinata* and *P. rigida* in southern New Jersey. Bulletin of the Torrey Botanical Club. 100(2): 94–102.

Lohrey, Richard E.; Kossuth, Susan V. 1990. *Pinus elliottii* Engelm. slash pine. In: Burns, Russell M.; Honkala; Barbara H., tech. coords. Silvics of North America: conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture: 338–347. Vol. 1.

Loomis, Robert M. 1975. Annual changes in forest floor weights under a southeast Missouri oak stand. Res. Note NC–184. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 3 p.

Lorimer, C.G. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology. 58: 139–148.

Lyon, L. Jack; Crawford, Hewlette S.; Czuhai, Eugene [and others]. 1978. Effects of fire on fauna: a state-of-knowledge review. Gen. Tech. Rep. WO–6. Washington, DC: U.S. Department of Agriculture, Forest Service. 22 p.

MacCleery, D. 1993. Understanding the role the human dimension has played in shaping America's forest and grassland landscapes. American Forests and Paper. 23(1): 1–9.

MacCleery, D. 1995. Resiliency: the trademark of America's forests. Forest Products Journal. 45(1): 18–28.

Martin, R.E.; Sapsis, D.B. 1992. Fires as agents of biodiversity: pyrodiversity promotes biodiversity. In: Proceedings of a symposium on biodiversity of northern California. Rep. 29. Berkeley, CA: Wildland Resources Center: 150–157.

Martin, W.H.; Boyce, S.G. 1993. Introduction: the southern setting. In: Martin, William H.; Boyce, Stephen G.; Echternacht, Arthur C., eds. Biodiversity of the Southeastern United States upland terrestrial communities. New York: John Wiley: 1–46.

Masters, R.E.; Wilson, C.W.; Bukenhofer, G.A.; Payton, M.E. 1996. Effects of pine-grassland restoration for red-cockaded woodpeckers on white-tailed deer forage production. Wildlife Society Bulletin. 24(1): 77–84.

Mattoon, Wilbur R. 1915. Life history of shortleaf pine. Agric. Bull. 244. Washington, DC: U.S. Department of Agriculture. 46 p.

McCarthy, E.F. 1933. Yellow-poplar characteristics, growth, and management. Tech. Bull. 356. Washington, DC: U.S. Department of Agriculture. 58 p.

McGee, C.E. 1979. Fire and other factors related to oak regeneration. In: Holt, H.A.; Fischer, B.C., eds. Regenerating oaks in upland hardwood forests: Proceedings of the 1979 John S. Wright forestry conference. West Lafayette, IN: Purdue University, Department of Forest and Natural Resources; Indiana Cooperative Extension Service: 75–81.

McKevlin, Martha R. 1996. An old-growth definition for evergreen bay forests and related seral communities. Gen. Tech. Rep. SRS–3. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 14 p.

McMahon, Charles K. 1977. Effect of forest emissions on air quality. In: Proceedings of a sumposium on fire by prescription. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region: 75–82.

McMahon, Charles K.; Ryan, Paul W. 1976. Some chemical and physical characteristics of emissions from forest fires. In: Proceedings of the annual meeting of the air pollution control association. APCA Pap. 76–2.3. [Place of publication unknown]: [Publisher unknown]. 69: 1–21.

McWhiney, G. 1988. Cracker culture: celtic ways in the Old South. Tuscaloosa, AL: University of Alabama Press. [Number of pages unknown].

Metz, L.J. 1954. Forest floor in the Piedmont region of South Carolina. In: Proceedings of the Soil Science Society of America. [Place of publication unknown]: [Publisher unknown]. 18(3): 335–338.

Mobley, Hugh E.; Jackson, Robert S.; Balmer, William E. [and others]. 1978. A guide for prescribed fire in southern forests. Atlanta: U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry. 40 p.

Monk, Carl D. 1968. Successional and environmental relationships of the forest vegetation of north central Florida. The American Midland Naturalist. 79(2): 441–457.

Morse, Larry E. 1988. Rare plants of Appalachian bedrock. Nature Conservancy Magazine. 38(2): 28–30.

Mueller, R.A.; Grimes, J.M., III. 1998. Regional climates. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands, ecology and management. Boca Raton, FL: Lewis Publishers/CRC Press: 87–101.

Mutch, R.W. 1970. Wildland fires and ecosystems: a hypothesis. Ecology. 51(6): 1046–1051.

Myers, R.K.; Van Lear, D.H. 1997. Hurricane-fire interactions in coastal forests of the South: a review and hypothesis. Forest Ecology and Management. 103: 265–276.

Myers, Ronald L.; Ewel, John J., eds. 1990. Ecosystems of Florida. Orlando, FL: University of Central Florida Press. 765 p.

Neary, Daniel G.; Currier, John B. 1982. Impact of wildfire and watershed restoration on water quality in South Carolina's Blue Ridge Mountains. Southern Journal of Applied Forestry. 6: 81–90.

Nelson, Ralph M. 1952. Observations of heat tolerance of southern pine needles. Stn. Pap. 14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 6 p.

Nelson, Ralph M.; Sims, Ivan H., Abell, Margaret S. 1933. Basal wounds on some Southern Appalachian hardwoods. Journal of Forestry. 31: 829–837.

Nelson, T.C. 1957. The original forests of the Georgia Piedmont. Ecology. 38(3): 390–397.

Niering, William A.; Goodwin, Richard H.; Taylor, Sally. 1970. Prescribed burning in southern New England: introduction to long-range studies. Proceedings: Tall Timbers fire ecology conference. [Tallahassee, FL]: [Tall Timbers Research Station]. 10: 267–286.

Olson, Steven D. 1996. The historical occurrence of fire in the central hardwoods, with emphasis on south central Indiana. Natural Areas Journal. 16(3): 248–256.

Oosting, H.J. 1942. An ecological analysis of the plant communities of the Piedmont, North Carolina. American Midland Naturalist. 28: 1–126.

Owsley, Frank L. 1945. Plain folk of the South. Baton Rouge, LA: Louisiana State University Press. 238 p.

Peet, Robert K.; Allard, Dorothy J. 1993. Longleaf pine vegetation of the southern Atlantic and eastern gulf coast regions: a preliminary classification. In: Proceedings, 18th Tall Timbers fire ecology conference: the longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 45–81.

Peterson, C.J. 2000. Catastrophic wind damage to North American forests and the potential impact of climate change. The Science of the Total Environment. 262: 287–311.

Phillips, Douglas R.; Abercrombie, James A., Jr. 1987. Pine-hardwood mixtures—a new concept in regeneration. Southern Journal of Applied Forestry. 11: 192–197.

Pinchot, G. 1899. A study of forest fires and wood production in southern New Jersey. In: Annual report of the State geologist, 1998. Trenton, NJ: New Jersey Geological Survey: 1863–1915.

Platt, W.J.; Evans, G.W.; Rathbun, S.L. 1988. The population dynamics of a long-lived conifer (*Pinus palustris*). American Naturalist. 131: 491–525.

Platt, W.J.; Schwartz, M.W. 1990. Temperate hardwood forests. In: Myers, R.; Ewel, J., eds. Ecosystems of Florida. Orlando, FL: University of Central Florida Press: 194–229.

Platt, William J.; Rathbun, S.L. 1993. Dynamics of an old-growth longleaf pine population. In: Proceedings, 18th Tall Timbers fire ecology conference: The longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 275–297.

Pyne, S.J.; Andrews, P.L.; Laven, R.D. 1996. Introduction to wildland fire. 2d ed. New York: John Wiley: 769 p.

Pyne, Stephen J. 1997. Fire in America: a cultural history of wildland and rural fire. 2d ed. Seattle: University of Washington Press. 680 p.

Ramenovsky, A. 1987. Vectors of death: the archeology of European contact. Albuquerque, NM: University of New Mexico Press. [Number of pages unknown].

Richardson, Curtis J.; Gibbons, J. Whitfield. 1993. Pocosins, Carolina bays, and mountain bogs. In: Martin, William H.; Boyce, Stephen G.; Echternacht, Arthur C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 257–310.

Richter, D.D.; Ralston, C.W.; Harms, W.R. 1982. Prescribed fire: effects on water quality and forest nutrient cycling. Science. 215: 661–663.

Robbins, Louise E.; Myers, Ronald L. 1992. Seasonal effects of prescribed burning in Florida: a review. Misc. Publ. 8. Tallahassee, FL: Tall Timbers Research, Inc. 96 p.

Robichaud, P.R.; Waldrop, T.A. 1994. A comparison of surface runoff and sediment yields from low- and high-severity site preparation burns. Water Resources Bulletin. 30(1): 27–34.

Ruffner, C.M.; Abrams, M.D. 1998. Lightning strikes and resultant fires from archival (1912–1917) and current (1960–1997) information in Pennsylvania. Bulletin of the Torrey Botanical Club. 125(3): 249–252.

Sandberg, D.V.; Pierovich, J.M.; Fox, D.G.; Ross, E.W. 1979. Effects of fire on air: a state-of-knowledge review. Gen. Tech. Rep. WO–9. Washington, DC: U.S. Department of Agriculture, Forest Service. 40 p.

Sanders, B.M.; Van Lear, D.H. 1987. Pre- and post- burn photo series for pine-hardwood logging slash in the Southern Appalachians. In: Proceedings, ninth conference on fire and forest meteorology. Boston: American Meteorological Society: 41–48.

Sanders, D.L.; Van Lear, D.H.; Guynn, D.C. 1987. Prescribed burning in mature pine-hardwood stands: effects on hardwoods and small mammals. In: Phillips, Douglas R., comp. Proceedings of the fourth biennial southern silvicultural research conference. Gen. Tech. Rep. SE–42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 93–96.

Schiff, A.L. 1962. Fire and water; scientific heresy in the Forest Service. Cambridge, MA: Harvard University Press. 229 p.

Shearin, A.T.; Bruner, Marlin H.; Goebel, N.B. 1972. Prescribed burning stimulates natural regeneration of yellow-poplar. Journal of Forestry. 70: 482–484.

Sims, I.H. 1932. Establishment and survival of yellow poplar following a clearcutting in the Southern Appalachians. Journal of Forestry. 30: 409–414.

Skeen, James N.; Doerr, Phillip D.; Van Lear, David H. 1993. Oak-hickory-pine forests. In: Martin, L; William, H.; Boyce, Stephen G.; Echternacht, Arthur C., eds. Biodiversity of the Southeastern United States: upland terrestrial communities. New York: John Wiley: 1–33.

Smith, B.D. 1994. The emergence of agriculture. New York: Scientific American Library. [Number of pages unknown].

Southern Appalachian Man and the Biosphere (SAMAB). 1996. The Southern Appalachian assessment terrestrial technical report. Rep. 5 of 5. Southern Appalachian man and the biosphere program. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 288 p.

Spurr, Stephen H.; Barnes, Burton V. 1980. Forest ecology. 3d ed. New York: John Wiley. 687 p.

Stanturf, J.A.; Schoenholtz, S.H. 1998. Soils and landforms. In: Messina, M.G.; Conner, W.H., eds. Southern forested wetlands, ecology and management. Boca Raton, FL: Lewis Publishers/ CRC Press: 123–147.

Stewart, O.C. 1963. Barriers to understanding the influence of fire by aborigines on vegetation. In: Proceedings, second annual Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 117–126.

Stoddard, H.L. 1962. The use of fire in pine forests and game lands of the deep Southeast. In: Proceedings, first annual Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 31–42.

Storey, Theodore G.; Merkel, Edward P. 1960. Mortality in a longleaf-slash pine stand following a winter wildfire. Journal of Forestry. 58(3): 206–210.

Stout, I. Jack; Marion, Wayne R. 1993. Pine flatwoods and xeric pine forests of the southern (lower) Coastal Plain. In: Martin, William H.; Boyce, Stephen G.; Echternacht, Arthur C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 373–446.

Streng, Donna R.; Glitzenstein, Jeff S.; Platt, William, J. 1993. Evaluating effects of season of burn in longleaf pine forests: a critical literature review and some results from an ongoing long-term study. In: Proceedings, 18th Tall Timbers fire ecology conference: The longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 227–263.

Sutherland, E.K. 1997. History of fire in a southern Ohio second-growth mixed-oak forest. In: Proceedings, 11th central hardwood conference. Gen. Tech. Rep. NC–188. Columbia, MO: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 172–183.

Sutherland, E.K.; Grissimo-Mayer, H.; Woodhouse, C.A. [and others]. 1995. Two centuries of fire in a southwestern Virginia *Pinus pungens* community. In: Proceedings: inventory and management techniques in the context of catastrophic events: altered states of the forest. University Park, PA: Penn State University, Center for Statistical Ecology and Environmental Statistics. 14 p.

Swann, F.R., Jr. 1970. Post-fire response of four plant communities in south-central New York State. Ecology. 51: 1074–1082.

Swift, L.W., Jr.; Elliott, K.J.; Ottmar, R.D.; Vihnanek, R.E. 1993. Site preparation burning to improve Southern Appalachian pine-hardwood stands: fire characteristics and soil erosion, moisture, and temperature. Canadian Journal of Forest Research. 23: 2242–2254.

Teuke, Michael J.; Van Lear, David H. 1982. Prescribed burning and oak advanced regeneration in the Southern Appalachians. Res. Pap. 30. Macon, GA: Georgia Forestry Commission. 1 p.

Thor, Eyvind; Nichols, Gary M. 1974. Some effects of fire on litter, soil, and hardwood regeneration. In: Proceedings, 13th annual Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 317–329.

Tiedemann, Arthur R.; Conrad, Carol E.; Dieterich, John H. [and others]. 1979. Effects of fire on water: a state-of-knowledge review. Gen. Tech. Rep. WO–10. Washington, DC: U.S. Department of Agriculture, Forest Service. 28 p.

Toole, E.R.; McKnight, J.S. 1956. Fire effects in southern hardwoods. Fire Control Notes. 17(3): 1–4.

Ursic, S.J. 1970. Hydrologic effects of prescribed burning and deadening upland hardwoods in northern Mississippi. Res. Pap. SO–54. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15 p.

U.S. Department of Agriculture. 1976. Southern forestry smoke management guidebook. Gen. Tech. Rep. SE–10. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 140 p.

U.S. Department of Agriculture. 1988. The South's fourth forest. For. Resour. Rep. 24. Washington, DC: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Van Lear, D.H.; Danielovich, S.J. 1988. Soil movement after broadcast burning in the Southern Appalachians. Southern Journal of Applied Forestry. 12: 45–49.

Van Lear, D.H.; Johnson, V.J. 1983. Effects of prescribed burning in the Southern Appalachian and upper Piedmont forests: a review. For. Bull. 36. Clemson, SC: Clemson University, Department of Forestry. 8 p.

Van Lear, D.H.; Waldrop, T.A. 1989. History, uses, and effects of fire in the Appalachians. Gen. Tech. Rep. SE–54. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 20 p.

Van Lear, David H.; Waldrop, Thomas A. 1988. Effects of fire on natural regeneration in the Appalachian Mountains. In: Smith, H. Clay; Perkey, Arlyn W.; Kidd, William E., Jr., eds. Proceedings of a workshop: guidelines for regenerating Appalachian hardwood stands. Morgantown, WV: West Virginia University Books: 56–70.

Vogl, Richard J. 1976. A primer of ecological principles. Cypress, CA: Pyro Unlimited. 172 p. Book 1.

Vose, J.M.; Swank, W.T.; Clinton, B.D. 1994. Fire, drought, and forest management influences on pine/hardwood ecosystems in the Southern Appalachians. In: Proceedings of the 12th conference on fire and forest meteorology. Bethesda, MD: Society of American Foresters: 232–240.

Vose, J.M.; Swank, W.T.; Clinton, B.D. [and others]. 1997. Using fire to restore pine/hardwood ecosystems in the Southern Appalachians of North Carolina. In: Proceedings: first conference on fire effects on rare and endangered species and habitats. Fairfield, WA: International Association of Wildland Fire: 149–154.

Wade, D.D.; Brock, B.L.; Brose, P.H. [and others]. 2000. Fire in eastern ecosystems. In: Brown, J.K.; Smith, J.K., eds. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS–42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 53-96. Chapter 4. Vol. 2.

Wade, Dale; Ewel, John; Hofstetter, Ron. 1980. Fire in south Florida ecosystems. Gen. Tech. Rep. SE–17. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 125 p.

Wade, Dale D. 1981. Some ***Melaleuca***-fire relationships including recommendations for homesite protection. In: Proceedings, ***Melaleuca*** symposium. Tallahassee, FL: Florida Division of Forestry: 29–35.

Wade, Dale D. 1995. Florida certified burner's correspondence course. Hillsborough, FL: Hillsborough Community College Institute of Florida Studies. 156 p.

Wade, Dale D.; Forbus, Ken; Saveland, James. 1993. Photo series for estimating post-hurricane residues and fire behavior in southern pine. Gen. Tech. Rep. SE–82. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 19 p.

Wade, Dale D.; Johansen, R.W. 1986. Effects of fire on southern pine: observations and recommendations. Gen. Tech. Rep. SE–41. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 14 p.

Wade, Dale D.; Lunsford, James D. 1989. A guide for prescribed fire in the Southern United States. Tech. Publ. R8–TP 11. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 56 p.

Wahlenberg, W.G. 1946. Longleaf pine: its use, ecology, regeneration, protection, growth, and management. Washington, DC: Charles Lathrop Pack Forestry Foundation. 429 p. In association with: U.S. Department of Agriculture, Forest Service.

Wahlenberg, W.G. 1949. Forest succession in the southern Piedmont region. Journal of Forestry. 47: 713–715.

Wakeley, P.C. 1954. Planting the southern pines. Washington, DC: U.S. Department of Agriculture. Agricultural Monograph 18. 233 p.

Waldrop, Thomas A.; Brose, Patrick H. 1999. A comparison of fire intensity levels for stand replacement of Table Mountain pine (***Pinus pungens*** Lamb). Forest Ecology and Management. 113: 155–166.

Waldrop, Thomas A.; Buckner, Edward R.; Muncy, Jack A. 1985. Cultural treatments in low-quality hardwood stands for wildlife and timber production. In: Shoulders, Eugene, ed. Proceedings: third biennial southern silvicultural research conference. Gen. Tech. Rep. SO–54. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 493–500.

Waldrop, Thomas A.; Van Lear, David H.; Lloyd, F. Thomas; Harms, William R. 1987. Long-term studies of prescribed burning in loblolly pine forests of the southeastern Coastal Plain. Gen. Tech. Rep. SE–45. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 23 p.

Waldrop, Thomas A.; White, David L.; Jones, Steven M. 1992. Fires regimes for pine-grassland communities in the Southeastern United States. Forest Ecology and Management. 47: 195–210.

Walker, Joan. 1993. Rare vascular plant taxa associated with the longleaf pine ecosystems: patterns in taxonomy and ecology. In: Proceedings, 18th Tall Timbers fire ecology conference: The longleaf pine ecosystem: ecology, restoration and management. Tallahassee, FL: Tall Timbers Research Station: 105–125.

Walker, Laurence C.; Wiant, Harry V. 1966. Silviculture of shortleaf pine. Bull. 9. Nacogdoches, TX: Stephen F. Austin State College School of Forestry. 60 p.

Ware, Stewart; Frost, Cecil; Doerr, Phillip D. 1993. Southern mixed hardwood forest: the former longleaf pine forest. In: Martin, William H.; Boyce, Stephen G.; Echternacht, Arthur C., eds. Biodiversity of the Southeastern United States: lowland terrestrial communities. New York: John Wiley: 447–493.

Waring, R.H.; Schlesinger, W.H. 1985. Forest ecosystems: concepts and management. Orlando, FL: Academic Press. 340 p.

Wear, D.N.; Abt, R.; Mangold, R. 1998. People, space, and time: factors that govern forest sustainability. In: Transactions, 63rd North American wildlife and natural resource conference. Washington, DC: Wildlife Management Institute: 348–361.

Wells, B.W. 1928. Plant communities of the Coastal Plain of North Carolina and their successional relations. Ecology. 9: 230–242.

Wells, B.W.; Shunk, I.V. 1931. The vegetation and habitat factors of the coarser sands of the North Carolina Coastal Plain. Ecological Monographs. 1(4): 465–521.

Wells, Carol G.; Campbell, Ralph E.; DeBano, Leonard F. [and others]. 1979. Effects of fire on soil: a state-of-knowledge review. Gen. Tech. Rep. WO–7. Washington, DC: U.S. Department of Agriculture, Forest Service. 34 p.

Wendel, G.W.; Smith, H. Clay. 1986. Effects of a prescribed fire in a central Appalachian oak–hickory stand. Res. Pap. NE–594. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.

Wenger, Karl F. 1958. Silvical characteristics of pond pine. Stn. Pap. 91. Asheville, NC: U.S. Department of Agriculture, Forest Service, South-eastern Forest Experiment Station. 13 p.

Wharton, C.H. 1977. The natural environments of Georgia. Atlanta: Georgia Department of Natural Resources. 227 p.

Whelan, R.J. 1995. The ecology of fire. New York: Cambridge University Press. 346 p.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26: 1–69.

Williams, C.E.; Johnson, W.C. 1992. Factors affecting recruitment of *Pinus pungens* in the Southern Appalachian Mountains. Canadian Journal of Forest Research. 22: 878–887.

Williams, Charles E. 1998. History and status of Table Mountain pine-pitch pine forests of the Southern Appalachian Mountains (U.S.A.). Natural Areas Journal. 18(1): 81–90.

Williams, Donvilla L.; Waldrop, Thomas A. 1995. Felling and burning to prepare Southern Appalachian sites occupied with mountain laurel. In: Edwards, M. Boyd, ed. Proceedings of the eighth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–1. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 623–625.

Williams, M. 1992. Americans and their forests. New York: Cambridge University Press. 599 p.

Wood, G.W., ed. 1982. Prescribed fire and wildlife in southern forests. Proceedings of a symposium. Georgetown, SC: The Belle W. Baruch Forest Science Institute of Clemson University. 170 p.

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U

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Wear, David N.; Greis, John G., eds. 2002. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.

The southern forest resource assessment provides a comprehensive analysis of the history, status, and likely future of forests in the Southern United States. Twenty-three chapters address questions regarding social/economic systems, terrestrial ecosystems, water and aquatic ecosystems, forest health, and timber management; 2 additional chapters provide a background on history and fire. Each chapter surveys pertinent literature and data, assesses conditions, identifies research needs, and examines the implications for southern forests and the benefits that they provide.

Keywords: Conservation, forest sustainability, integrated assessment.